NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

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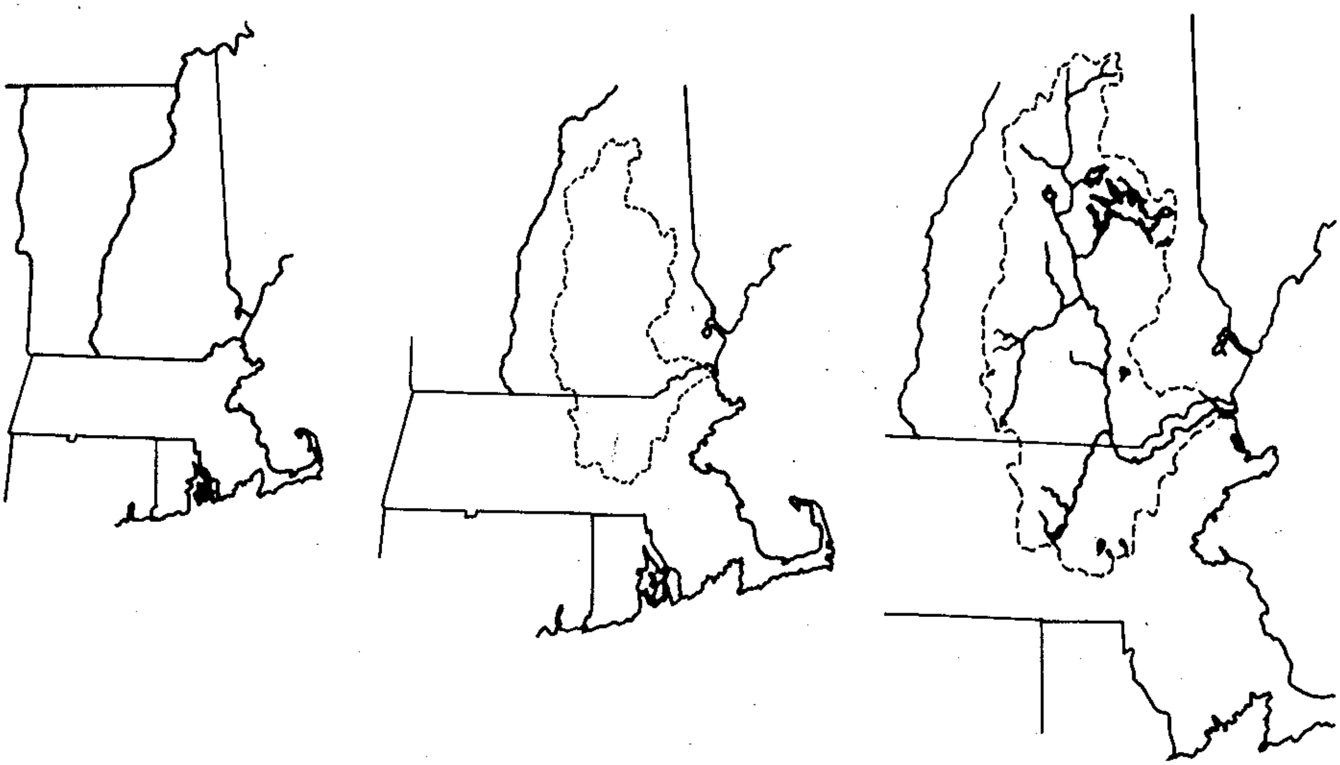
MERRIMACK RIVER BASIN WATER SUPPLY STUDY



JANUARY 1977

MERRIMACK RIVER WATER SUPPLY PROJECT

TECHNICAL REPORT

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SECTION A

THE STUDY AND REPORT

1. Information on the authorization of this study, the study's role toward the development of a regional water supply plan and a description of the study is presented here as an introduction to the contents and findings of this report.

PURPOSE AND AUTHORITY

2. The purpose of this study is to investigate the water supply needs of communities within the Massachusetts portion of the Merrimack River Basin. In addition, the report evaluates the potential which the Merrimack River may have as a long range source of water supply, for the eastern Massachusetts region. The possibility of servicing portions of southeastern New Hampshire from the river within Massachusetts was also considered and is reported upon. Economic, environmental and socio-economic criteria were used in evaluating the feasibility of a number of proposals to supply water to the region. The effects of the plans and alternatives on allied water uses such as hydro-electric power generation, fisheries resources and other uses were considered and a discussion of these effects is included in the report.

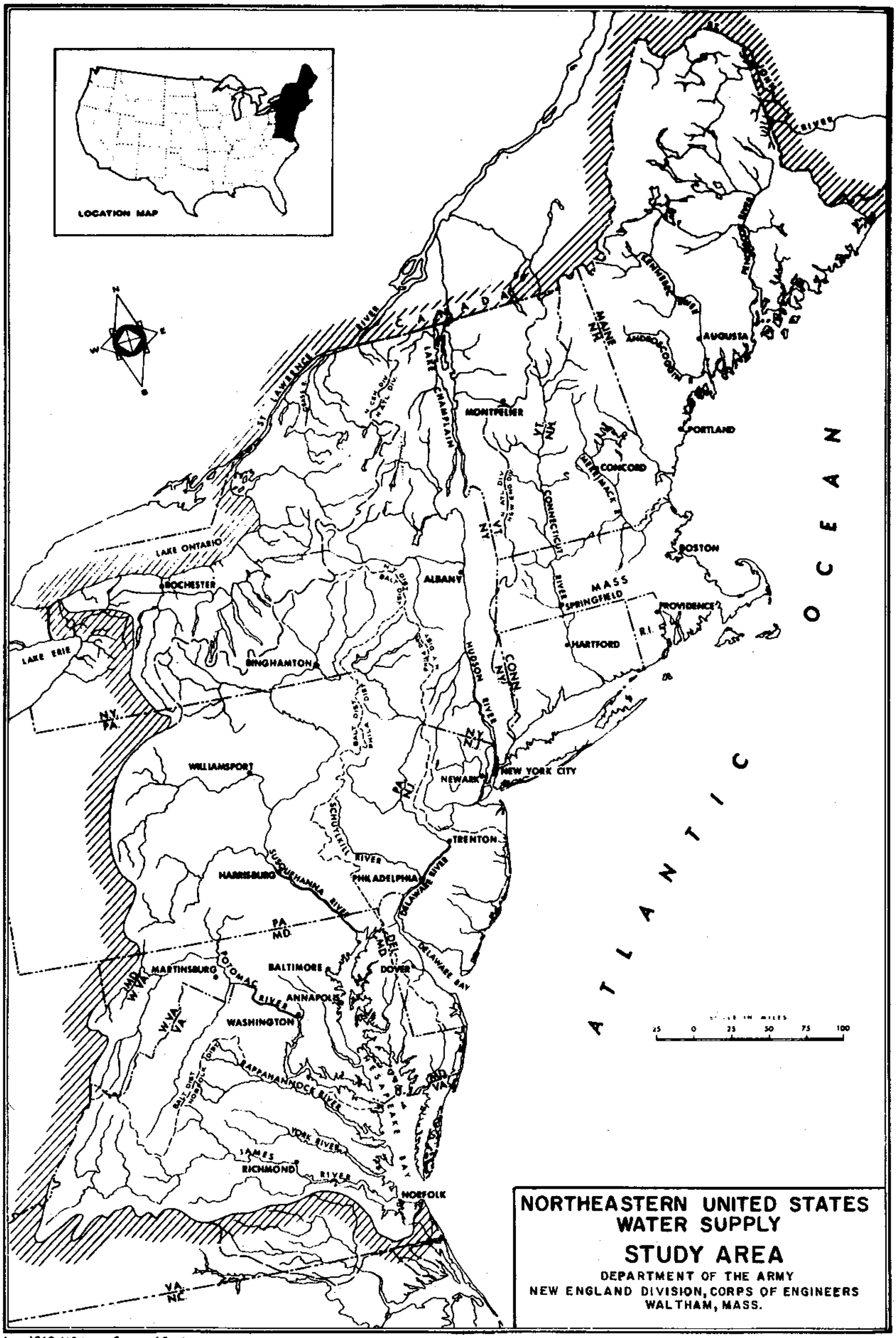
3. The study and report are in partial fulfillment and in compliance with the Northeastern United States Water Supply Study (NEWS) authorized by Congress under Title I of Public Law 89-298, enacted on 27 October 1965. As stated in that Act:

"(a) Congress hereby recognizes that assuring adequate supplies of water for the great metropolitan centers of the United States has become a problem of such magnitude that the welfare and prosperity of this country require the Federal Government to assist in the solution of water supply problems. Therefore, the Secretary of the Army, acting through the Chief of Engineers, is authorized to cooperate with Federal, State, and local agencies in preparing plans in accordance with the Water Resources Planning Act (Public Law 89-80) to meet the long-range water needs of the northeastern United States. This plan may provide for the construction, operation, and maintenance by the United States of (1) a system of major reservoirs to be located within those river basins of the Northeastern United States which drain into the Chesapeake Bay, those that drain into the Atlantic Ocean north of the Chesapeake Bay, those that drain into Lake Ontario, and those that drain into the Saint Lawrence River, (2) major conveyance facilities by which water may be exchanged between these river basins to the extent found desirable in the national interest, and (3) major purification facilities. Such plans shall provide for appropriate financial participation by the States, political subdivisions thereof, and other local interests.

(b) The Secretary of the Army, acting through the Chief of Engineers, shall construct, operate, and maintain those reservoirs, conveyance facilities, and purification facilities, which are recommended in the plan prepared in accordance with subsection (a) of this section, and which are specifically authorized by law enacted after the date of enactment of this Act.

(c) Each reservoir included in the plan authorized by this section shall be considered as a component of a comprehensive plan for the optimum development of the river basin in which it is situated, as well as a component of the plan established in accordance with this section." A plan of the NEWS study area is shown on Plate 1.

The Chief of Engineers, in turn, assigned responsibility for the NEWS Study to the Division Engineer, North Atlantic. The Merrimack River Water Supply Study was done by the New England Division in coordination with the North Atlantic Division.



June 1969 - US Army, Corps of Engineers

PLATE I

SCOPE OF THE STUDY

4. The studies presented in this report are directed toward developing a plan for utilizing the Merrimack River as a water supply source for eastern Massachusetts, and possibly southeastern New Hampshire. Because the State of Rhode Island has indicated its preference for intra-State development of water supply sources rather than a large regional inter-State connection, and alternatives have been proposed to meet Rhode Island's future needs, the State of Rhode Island was not considered by this report. All reasonable alternative plans to solve the region's future water supply problems were considered and several plans were studied in detail including economic, environmental and socio-economic effects. All of the plans were also evaluated to determine their compatability with the development of a regional plan. The selection of the plan was made only after full consideration of all its effects including those offered by interested citizens, New Hampshire and Massachusetts State agencies, and other Federal agencies.

STUDY PARTICIPANTS AND COORDINATION

5. The Corps of Engineers was given responsibility for the conduct of the Northeastern United States Water Supply Study (NEWS) and this report is part of the larger NEWS effort. The study staff, however, used a large amount of information from studies of other agencies in preparing this report.

6. The studies and investigations were prepared with the cooperation of a large number of agencies. Included in these agencies were the following:

Massachusetts Water Resources Commission
Metropolitan District Commission
Massachusetts Fish & Game
New Hampshire Office of State Planning
New Hampshire Water Supply and Pollution Control Commission
New Hampshire Fish & Game
U. S. Fish and Wildlife Service
Northern Middlesex Regional Planning Commission
Merrimack Valley Regional Planning Commission
Montachusetts Regional Planning Commission

Central Massachusetts Regional Planning Commission
Metropolitan Area Planning Council
Old Colony Planning Council
Southeastern Massachusetts Regional Planning and Economic Development Commission
Northern New Hampshire Regional Planning Commission
Southern Rockingham Regional Planning Commission (N. H.)

7. The study effort provided for direct participation and coordination by Federal, State and local agencies as well as interested conservation and citizen groups. As a method of insuring full participation, a series of formal public meetings, progress meetings and informal informational meetings was held to discuss alternative plans.

8. Seven public meetings within New England were held at the outset of the NEWS investigations in May and June 1967. During a series of Public Meetings in December 1971 - January 1972 and July 1972, the role of the Merrimack River as a potential regional water supply source was described and discussed. In July 1975, a plan formulation public meeting was held at Lawrence, Massachusetts, a community within the Merrimack River Basin. At this meeting, a presentation was made of all alternatives considered. Considerable discussion followed the presentation and the comments and suggestions offered by those in attendance were utilized in the formulation of the selected short term plan and in the formulation of long term alternatives.

THE REPORT

9. The report includes the study's authority, the physical and economic resources of the Merrimack River Basin, problems and needs within the basin and the eastern Massachusetts region, and alternative methods of providing needed water supply to the region. The evaluation of all alternatives was conducted using the "Principles and Standards" adopted for use in all Federal water resource development planning. Recommendations on a course of action to meet both short and long range water supply needs are presented.

PRIOR STUDIES AND REPORTS

10. A large number of reports have been prepared on the various rivers within the Merrimack River Basin. These reports, prepared by Federal, State and Regional Agencies, cover many areas of resource interest, both in the public and private sectors. For example, as part of the Corps of Engineers' on-going flood control program, there have been completed, beginning in calendar year 1938 and continuing through 1970 a total of 11 reports in response to separate Congressional directives. In the area of navigation, from 1826 through 1940 the Corps had submitted 28 separate reports, while 7 summary reports on flood plan information have been submitted as guides to local municipalities. A complete listing was not considered necessary for this report, as none of these prior Federal reports address themselves to water supply planning. A few of the more pertinent Federal reports are included in the following section.

11. In the Merrimack River Basin, the land and water resources and flood control needs have been considered in detail in the following Federal survey reports:

CORPS OF ENGINEERS

a. Water Resources Investigation, Merrimack River Basin. This report of survey scope covers the entire Merrimack River Basin. The report was prepared as a result of Congressional resolutions adopted 9 February 1961 and 9 April 1964 and published in August 1972 by the New England Division, Corps of Engineers. The water resource problems and solutions of the North Nashua and Sudbury River watersheds were covered in reports described in following paragraphs. This report determines the advisability and economic feasibility of flood protection, navigation and other water resource development in the remainder of the basin and makes specific recommendations for programs and measures needed for the basin.

b. North Nashua River Basin. An interim report printed as Senate Document No. 113, 89th Congress, 2nd Session, reviewed the need for flood control and allied purposes on the North Nashua River and tributaries. The report recommended additional protection consisting of four reservoirs, restoration of an existing local flood protection project, and two additional improvements for local protection. These projects were authorized by the 1966 Flood Control Act.

c. Sudbury River Basin. Saxonville Local Protection. An interim report printed as Senate Document No. 61, 89th Congress, 1st Session, reviewed the need for flood control and allied purposes on the Sudbury River in the village of Saxonville in the town of Framingham, Massachusetts. The report recommended a local protection project consisting of dikes, flood-walls, a pumping station and related works. The project was authorized by the Flood Control Act of 1965. Plans and specifications have been completed, and construction was begun in the spring of 1976.

FEDERAL AGENCIES

12. In addition to the reports listed above, several other Federal reports considering the land and water resources of the Merrimack River Basin have been used:

a. "308" Report. A report dated 1 December 1930 and printed as House Document No. 649, 71st Congress, 3rd Session, found that navigation, flood control, power development and irrigation improvements in the basin were not warranted at that time.

b. 1938 Report. A report dated 18 May 1938 and printed as House Document No. 689, 75th Congress, 3rd Session, presented a comprehensive plan for flood control in the basin. A plan, consisting of four reservoirs, all located in New Hampshire, and related flood control works, was recommended for development. The plan was authorized in compliance with Public Law No. 738, 74th Congress, as amended by Public Law No. 761, 75th Congress.

c. Survey Report of April 1940. A report on navigation, flood control and water power recommended the addition of West Peterboro (Edward MacDowell) Reservoir to the authorized flood control system. The report also concluded that "Additional flood control on the Pemigewasset River can be obtained most economically through a multiple-purpose development at Livermore Falls in conjunction with Franklin Falls Reservoir." This report was not submitted to Congress.

d. Comprehensive Plan for Flood Control. This report, dated March 1947, was presented to the states concerned with flood control in the Merrimack River Basin. The report gave the states advance information of the flood control plan for the basin. The report proposed seven reservoirs for flood control, and of the seven, three were to include power storage with provision for future addition of generating facilities.

e. NENYIAC Report. Flood control and allied water uses in the Merrimack River Basin are considered in Part 2, Chapter XV, "Merrimack River Basin," of The Resources of the New England-New York Region, a comprehensive survey of the land, water and related resources of the New York-New England region. Prepared by the New England-New York Inter-Agency Committee, the report was referred in 1955 to the Governors and agencies concerned for comment, and submitted to the President of the United States by the Secretary of the Army on 27 April 1958. Part I and Chapter I of Part 2 are printed as Senate Document No. 14, 85th Congress, 1st Session.

f. "205" Report. A report on flood control and allied purposes in New England River basins, dated 30 June 1955, found that the flood problem in the Merrimack River Basin warranted construction of two reservoirs in addition to the three that had been completed. It stated that the proposed Hopkinton-Everett reservoir (completed in 1962) was adequately justified, but the construction of the other proposed Livermore Falls Reservoir "would have adverse effects upon the economy of the area and is not recommended at this time." This report was completed subsequent to the initial printing of NENYIAC (see above) but prior to the printing of the part of that report as a Senate Document.

g. Winnipesaukee River. A study of the Winnipesaukee River was the subject of the report by an engineer consultant firm for the New England Division in January 1957. The report describes solutions to the flood problems which would result from an increase in the maximum permissible discharge from Lake Winnipesaukee to the Winnipesaukee River. This increase had been proposed by the New Hampshire Water Resources Board as a solution to high water problems along the Lake Shore. The report recommended measures allowing the increased lake discharge, but the proposed work was not warranted for Federal participation by economic benefits realized at that time.

h. Massachusetts Coastal and Tidal Areas. A Hurricane Survey report entitled, "Massachusetts Coastal and Tidal Areas," was published 24 September 1965 as House Document No. 293, 89th Congress, 1st Session. The report recommended that no improvements for hurricane protection be undertaken by the United States in the Massachusetts coastal and tidal areas, except for authorized projects.

i. North Atlantic Regional Water Resources Study. The NAR Study is one of 20 regional framework comprehensive water and related land resources studies conducted throughout the United States under guidelines established by the Water Resources Council. The NAR Study was authorized by the 1965 Flood Control Act (Section 208, Public Law 89-298). The study objective was the establishment of a broad master plan or framework to serve as a basis for future regional water resources development and management. The requirements and needs of the people of the region were considered in analyzing water resource needs including water quality control, flood control, municipal and industrial water supply, irrigation and rural water supply, navigation, hydroelectric power, recreation, fish and wildlife and other environmental resources. The study was completed in 1972 and concluded that water quality maintenance is the key need of the Merrimack River Basin.

j. "Organizational, Legal and Public Finance Aspects of Water Supply for Southeastern New England, the Metropolitan Area of New York City - Northern New Jersey - Western Connecticut," July 1972. This report was prepared as part of the overall Northeastern United States Water Supply Study (NEWS). This report analyzed organizational, legal, and economic problems of water supply within the study area. Alternative solutions to the problems are described and discussed. The results of engineering studies supplemented by the results of this institutional feasibility constitute the tools with which the Corps of Engineers and other agencies and organizations concerned may reach a decision on which of the various alternatives more detailed study effort should be concentrated.

k. "Feasibility Report on Alternative Regional Water Supply Plans for Southeastern New England". This report was prepared in 1969 by the New England Division for the North Atlantic Division as part of the Northeastern United States Water Supply Study (NEWS).

This report assesses the capability of the public water supply systems within eastern Massachusetts and Rhode Island to meet future needs. Plans and alternatives are proposed which, when added to the present systems, would assure future adequate water supply for the study area and is being used as input to the overall NEWS report scheduled for completion in FY 77.

l. NEWS Wastewater Management Program Study. The NEWS Study has encountered extensive water pollution which severely limits the useable supply available in this region. The problem of inadequate waste management is evident through the region. The use of the Merrimack River for municipal and industrial purposes is becoming more suspect, as well as more difficult. Its utility as quality environment for fish and other aquatic life is seriously impaired. Water-based recreation is restricted and aesthetic enjoyment on the river is limited. These conditions make wastewater management a major consideration for the NEWS Study if adequate water supplies are to be assured. The Wastewater Management Program was undertaken within the planning authority of the Corps of Engineers for a study of water supply for the Northeastern United States (NEWS). A feasibility study which investigated and evaluated all appropriate alternatives for total wastewater management was completed in 1971. A survey scope study was then initiated in 1972, and completed in November 1974. This study concentrated its effort on the 24 cities and towns along the mainstem Merrimack within Massachusetts. The report presents a wastewater management plan for the study area which could serve as the basis for implementation of wastewater systems. The report has been reviewed by the Board of Engineers for Rivers and Harbors which has agreed with the findings of the report and recommended that the report be forwarded to the Congress for information.

m. Winnipesaukee River. A resolution adopted by the Committee on Public Works of the House of Representatives, United States, adopted 14 July 1970, requested a review of the reports of the Chief of Engineers on the Merrimack River, Massachusetts and New Hampshire, with specific reference to Winnipesaukee River, New Hampshire, with a view to determining the advisability of improvements in the interest of flood control and allied purposes. The study will center on solving the problems of flooding, enhancing recreation development and permitting greater flow regulation. This study was initiated in FY 73.

STATE AGENCIES

13. Massachusetts State Agencies with responsibility in water supply planning, construction and certification are the Department of Natural Resources, the Metropolitan District Commission, and the Department of Public Health. Studies regarding the present water supply situation in the Boston Metropolitan Region have provided a significant input to the preparation of this report. Some of the regional reports include:

a. Metcalf and Eddy Engineers, Inc., Report on Public Water Supply Resources of the Parker River Basin, Prepared for the Massachusetts Water Resources Commission, Division of Water Resources, May 1973.

b. Massachusetts Senate Document No. 1216, Report of the Metropolitan District Commission to Make an Investigation and Study Relative to Increasing the Sources of Water to the Metropolitan Water District and Increasing Membership of Said District, December 1971.

c. Hill and Lind, Inc., Report on Ipswich River District Water Supply, Prepared for the Massachusetts Water Resources Commission, Division of Water Resources, September 1971.

d. Massachusetts Senate Document No. 1008, Report of the Metropolitan District Commission Relative to the Diversion of Excess Water from Millers River and Other Sources into Quabbin Reservoir, March 1971.

e. Massachusetts House Document No. 5543, Report of the Special Commission Relative to Providing Funds for Extension and Development of Water Supply Sources and Diversion of Water from Connecticut River to Quabbin Reservoir, May 1970.

f. Massachusetts Senate Document No. 1230, Report of the Metropolitan District Commission Relative to the Diversion of Excess Water from Millers and Other Sources into Quabbin Reservoir as Required by Chapter 46, 1967, March 1969.

g. Massachusetts Senate Document No. 1095, Report of the Metropolitan District Commission Relative to the Diversion of Excess Water from Millers River and Other Sources into Quabbin Reservoir, December 1966.

h. Massachusetts Senate Document No. 808, Special Report of the Metropolitan District Commission Relative to Diversion of Excess Water from Millers River into Quabbin Reservoir, January 1966.

i. Massachusetts House Document No. 4100, The Public Water Supply Resources of the Ipswich River, Prepared for the Massachusetts Water Resources Commission, Division of Water Resources, January 1965.

14. In the State of New Hampshire, responsibility for the adequacy and safety of public drinking water supplies lies with the New Hampshire Water Supply and Pollution Control Commission. In addition to this agency's work, a large amount of regional water supply planning has been conducted by regional planning agencies and the private investor-owned water supply companies. Reports prepared by New Hampshire State Agencies and reviewed as part of this study include:

a. Anderson-Nichols and Company, Inc., Public Water Supply Study, Phase One Report, Prepared for the New Hampshire Department of Resources and Economic Development, May 1969.

b. Anderson-Nichols and Company, Inc., Public Water Supply Study, Phase Two Report, Prepared for the Office of State Planning, New Hampshire, March 1972.

REGIONAL PLANNING AGENCIES

15. Seven regional planning agencies in Massachusetts and New Hampshire are located in the vicinity of, and upstream or downstream from, this study's proposed project intake. Those within Massachusetts are Montachusett Regional Planning Commission, Northern Middlesex Area Commission, Merrimack Valley Regional Planning Commission, and the Metropolitan Area Planning Council. In New Hampshire, the Southern New Hampshire Planning Commission and the Nashua Regional Planning Commission have been active. A number of reports regarding future water supplies of the Agencies' respective regions have been prepared and include:

a. Alonzo B. Reed, Inc., Report Relative to the Central Massachusetts Comprehensive Water Supply Study, Prepared for Central Massachusetts Regional Planning Commission and the Metropolitan District Commission, June 1973.

b. Curran Associates, Inc., Regional Plan for Water Supply and Wastewater, Montachusett Region, Prepared for Montachusett Regional Planning Commission, April 1973.

c. Camp, Dresser and McKee Engineers, Inc., Alternative Regional Water Supply Systems for the Boston Metropolitan Area, Prepared for Metropolitan Area Planning Council, February 1971.

d. Metcalf and Eddy Engineers, Inc., Water Supply and Sewage Planning in Central Merrimack Valley Region, Prepared for Central Merrimack Valley Regional Planning Commission, September 1970.

e. Northern Middlesex Area Commission, Regional Utilities, Volume 2, Alternative Plans for Sewer and Water Facilities, July 1969.

f. Howard, Needles, Tammen & Bergendoff, Regional Water Quality Management Plan, Prepared for the Nashua Regional Planning Commission, December 1973.

19. In addition to reports prepared by planning groups which include communities within the Merrimack River Basin, water supply studies prepared by regional groups in eastern and central Massachusetts were also reviewed. These included:

a. Metcalf and Eddy Engineers, Inc., Report to Old Colony Planning Council, Brockton, Massachusetts, on Phase Three of Water and Sewerage Study, March 1971.

b. Tippetts - Abbett - McCarthy - Stratton, Regional Study for Water Supply, Sewerage Disposal and Drainage, Southeastern Massachusetts, Phase II, Prepared for Southeastern Massachusetts Regional Planning Commission, April 1969.

SECTION B

RESOURCES AND ECONOMY OF THE STUDY AREA

1. The purpose of this section is to describe the resources, both natural and human, of the Merrimack River Basin and the basin's current and projected economic conditions. (This background information can then be used in evaluating the needs which have been identified and the plans considered to meet these needs.)

ENVIRONMENTAL SETTING AND NATURAL RESOURCES

2. The Merrimack River Basin is located in south-central New Hampshire and northeastern Massachusetts, as shown on Plate 2. The fourth largest of the river basins lying wholly in New England, it extends from the White Mountain region of New Hampshire southward into the rolling hills of eastern Massachusetts, and covers an area of 5,010 square miles, of which about 4 percent, or 200 square miles, is constituted of lakes and ponds. The New Hampshire portion of the basin amounts to 3,810 square miles, or 76 percent of the basin area, and the Massachusetts portion amounts to 1,200 square miles, or 24 percent. The basin has a length in a north-south direction of about 134 miles and a maximum width in an east-west direction of 68 miles. It is bounded by the Connecticut River Basin on the west and northwest, the Saco and Piscataqua River Basins on the northeast and east, the New Hampshire and Massachusetts coastal areas on the east and southeast, and the Blackstone River Basin on the south.

SURFACE-LAND FORMS-ELEVATION

3. The Merrimack River watershed divides naturally into three sections. The northern mountain section, drained by the Pemigewassett and Winnipesaukee Rivers, is rough and steep with elevations

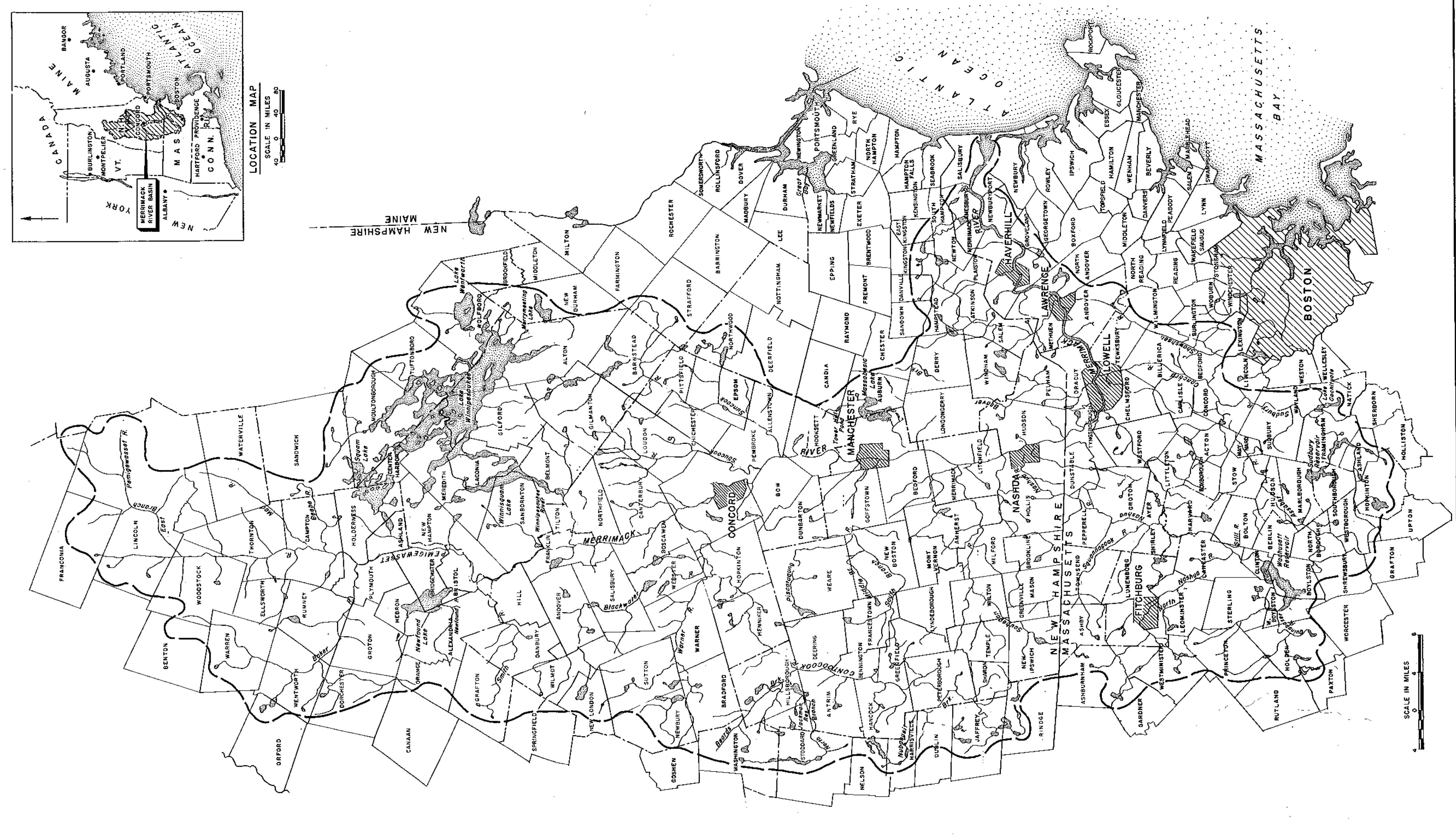
ranging from 1,000 to 5,000 feet above sea level. Mount Lafayette, at elevation 5,249 feet mean sea level, is the highest point in the basin. Lake Winnipesaukee and other large lakes in the northern mountain section occupy a major depression that was scooped out of the upland surface on the east side of the basin by glacial action. The central upland section, drained by the Contoocook, Suncook, and Souhegan Rivers, is a dissected, rolling plateau with elevations ranging from 200 to 2,000 feet above sea level and occasional peaks as high as 3,000 feet. The southern lowland region, drained by the Nashua and Concord Rivers, is low and rolling with elevations ranging up to 300 feet above sea level, and numerous ponds and swamps.

GEOLOGY-SOILS-MINERAL RESOURCES

4. Most of the Merrimack River Watershed is located in the New England Upland, a maturely dissected plain. The lower portion of the basin in New Hampshire and northeastern Massachusetts is located along the Seaboard Lowland. The present drainage pattern in the basin was developed at the close of the glacial period by meandering runoff crossing the lower areas of a complex blanket of glacial and glacial-alluvial overburden. The bedrock of the basin consists of hard crystalline Paleozoic rocks. Granite abounds: the White Mountains are underlain by granite, granite gneiss and schist. Granite, along with coarse porphoritic gneiss fringes the basin on the west and on the east in the Lake Winnipesaukee depression. Below Lowell, there are varieties of granite to the north of the river.

5. The basin is covered by the sheet of glacial till which is general throughout New England and composed of variable, unstratified, silty, gravelly sand and clays, with interspersed cobbles and boulders. The cover is usually thin on the hilltops and deep in the valleys. Bedrock is often exposed in the hilly uplands and occasionally in the valleys where diverted streams have cut through the till. Deposits of pervious materials laid down by melt-water streams from the glacier occur throughout the basin, especially in the lower portion of the watershed, as sand and gravel kames, terraces, deltas and outwash plains. Due to the warping of the earth's crust during and immediately after the waning of the ice sheet, marine estuaries extended inland as far as Manchester, New Hampshire. This accounts for the marine clay and silt found in the valley bottoms in the lower part of the basin.

6. Dimension and crushed granite and sand and gravel are the most important mineral products in the basin. Minor amounts of the



NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

MERRIMACK RIVER STUDY

THE MERRIMACK RIVER BASIN

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

pegmatite minerals, feldspar, mica and beryl were mined until recently in the Grafton-Rumney area. Production of minerals in the basin has included, in addition to the above, clay, copper, fuller's earth, garnet, graphite, limestone, nickel, peat, silica, soapstone, traprock, zinc, and lead. Many of the former mining operations ceased because competition from other sources and reductions in prices paid for the minerals made the operations uneconomical. The basin potential in mineral resources has never been fully explored.

BIOLOGICAL PRODUCTIVITY

7. The Merrimack River system and its lakes and ponds support a varied fishery. Major New Hampshire lakes, including Lake Winnipesaukee, Winnisquam, Squam, Little Squam, and Newfound, provide cold-water fishing. Some of these offer a warm-water fishery also. The Massachusetts portion of the basin contains 14 ponds currently managed for both trout and warm-water species. Lake and pond warm-water species in the basin include smallmouth and largemouth bass, brown bullheads, chain pickerel, yellow and white perch and sunfish.

8. The mainstem and numerous tributary rivers support a variety of fishing also. The more important tributary fisheries are on the Squannocook (the entire tributary system has been reclaimed for trout); the Souhegan above Milford; the Piscataquog and its two main branches above Goffstown; the Soucook; the Contoocook and tributaries; and the Pemigewasset above Lincoln and its tributary Smith River. Brook trout, an important game fish, is widely distributed, while rainbows and browns are found in some stream segments. A major portion of the basin is stocked moderately to heavily. The outstanding bass fishery found on the mainstem of the Merrimack receives only light usage because of the pollution. The lower portion of the Contoocook, the second largest Merrimack tributary, also provides abundant bass fishing. Walleyes also are caught there and in the mainstem in the vicinity of Hooksett, New Hampshire.

9. In addition to the existing fishery, historically the Merrimack River provided spawning grounds for several species of anadromous fish. Pollution and the construction of numerous dams have caused the virtual elimination of annual runs of fish in the Merrimack. Federal fishery agencies as well as those of Massachusetts and New Hampshire are keenly interested in the restoration of these historical fish runs to the river. In 1969, an agreement was reached between

these agencies to restore annual runs of 11,000 Atlantic Salmon and 1,000,000 shad. Based on the fishery agencies' time table, the salmon and shad runs should be sufficiently established by 1980 to support a broad stock program, while a limited sports fishery should be available by 1985 and the full runs are expected by 1990. If these objectives are realized, the economic value of the fishery could be substantial particularly when viewed from a recreational perspective.

10. Wildlife species in the basin are numerous, reflecting the varied habitat. Hunter expenditures constitute an important factor in basin economy. The white-tailed deer is the most hunted of all game species although black bear are also sought. Small game taken includes ruffled grouse, varying hare, gray squirrel, pheasant, cottontails, and woodcock. Trapping is of moderate economic importance and includes muskrat, beaver, mink, racoon, and otter. Forest game species are more predominant in the northern and central sections, while farm game comprises the most important species in the southern section. Massachusetts manages upland game areas for public hunting at Westboro and Fort Devens.

11. The largest waterfowl area in the basin is the State-managed Merry-meeting marshes on a tributary to Lake Winnipesaukee in New Hampshire. A second, but more important, large area lies at the marsh and mudflat complex. Adjacent to the latter area is the Parker River National Wildlife Refuge. The Federal Water Resource construction programs of the Corps of Engineers and the Soil Conservation Service have provided recent opportunities for waterfowl habitat development, notably areas at the Corps Hopkinton-Everett Lakes project and in the Baker, Concord and Souhegan watersheds. In addition to the improved areas, there are many slow-flowing streams, and ponds with weedy shorelines and shallow coves, along with the basin's numerous beaver ponds, providing good waterfowl habitat.

LAND USE

12. Dense stands of timber once covered practically all land in the Merrimack River Basin. Clearing began with settlements three centuries ago and reached its peak about the middle of the 19th century when less than half of the land area remained in forest. With the decline of agriculture and the move to urban living, much of the cleared land reverted to forest. Transition in land use is still in progress and about 70 percent of the basin is now covered by forests.

13. The northern mountain section, drained by the Pemigewasset and Winnipesaukee Rivers, is heavily forested with scattered part-time farms in the south where the terrain is less rugged. About one percent of this northern area is used for crops or open pasture. The central upland section, drained by the Contoocook, Suncook, Soucook, and Souhegan Rivers, is essentially a rough wooded plateau with farm land concentrated in valleys or on smooth ridges. About 14 percent of this upland area is devoted to crop and open pasture uses. The southern lowland region, drained by the Nashua, Concord, and lower Merrimack Rivers, is low and rolling with large flat areas. Much of these flats are poorly drained. Nearly ten percent of this lowland region is used for crops and open pastures.

14. Considerable improvement in watershed conditions can be obtained by shifting land use into better conformity with the basin's physical capabilities of the soil, such as discontinuance of grazing on steep slopes with shallow soil and the establishment of a forest cover on such areas. Improved streamflow control would alleviate stream channel erosion and damaging sedimentation during periods of high runoff.

15. Although practically all forests are now second growth, substantial areas have reached sawtimber size. There are stands of seedlings and saplings, with some areas poorly stocked, and with heavily cut-over land still remaining. Nearly all land is capable of producing large quantities of commercially valuable timber. The basin's potential for timber production is great and with good management and adequate protection, its forests may again contribute materially to the needs of timber-based industries.

16. Mineral production within the basin is of relatively minor importance and the need exists to increase the knowledge of the basin's mineral resources. Of possible economic interest in the future are andalusite, diatomite, nepheline syenite, scapolite, spodumene, and zinc. An occurrence of the tungsten mineral, scheelite, is probably too small for economic exploitation at this time.

CLIMATE

17. The basin weather is influenced by conflicting air masses -- cool, dry air from the Polar regions to the northwest and moisture-bearing tropical marine air from the south and east. Interaction of these air

currents brings to the basin a succession of alternating, low pressure, or cyclonic disturbances, accompanied by snow or rain, and high-pressure or anti-cyclonic disturbances, characterized by cool, dry conditions.

18. Average annual temperature in the basin is about 46° Farenheit, ranging from 49° in the southern portion to 43° in the central and northern areas. Average monthly temperatures vary widely, ranging from between 67° and 73° in July and August to between 19° and 27° in January and February, depending on the location. Extremes in daily temperature range from occasional highs in the 100's to infrequent lows in the minus 20's and 30's.

19. The annual precipitation over the entire basin averages about 42 inches with rather uniform distribution throughout the year. There is somewhat more precipitation in the upper basin during the summer months than at other times of the year. In winter, precipitation in the central and upper basin is practically all in the form of snow and, in the southern portion, alternately in snow and rain. Snowfall varies from an average of 50 inches in the south to 83 inches in the higher elevations of the northern portion. Water content of snow cover is usually from 5 to 7 inches, but reaches a maximum of about 14 inches in the Pemigewasset River watershed in the springtime.

20. Continental storms, coastal storms and thunderstorms are the three types of precipitation-producing storms occurring over the basin. The continental storms, originating in the western or central portion of the United States move easterly or northeasterly and may be rapidly moving, intense storms or the stationary frontal type. Not limited to any one season, they follow one another with varying intensities and at more or less regular intervals.

21. The most severe of the coastal storms are tropical hurricanes originating in the South Atlantic Ocean or western Caribbean Sea. Their general path is to the south and east of New England, but they are, at times, diverted over the mainland by other cyclonic weather patterns. Hurricanes generally occur during the late summer or fall months with the highest incident in August and September. Other types of coastal storms generally originate near the Middle Atlantic States and travel northward along the coastline. Their occurrence is most frequent during the autumn, winter and spring months. Thunderstorms can result from local convective action or be associated with a broad frontal weather system.

22. The long term normal rainfall of about 42 inches in the Merrimack River Basin is actually the average of many highs and lows. When rainfall is below average for a period of time, the area experiences what is referred to as a "drought." In this case, a drought is defined as a prolonged period of precipitation deficiency which seriously affects both riverflow and water supplies. The severe drought of the sixties had a great impact upon water supply and agriculture in the Merrimack basin. Ground water storage is the primary source of streamflow between periods of rainfall and generally aquifers are replenished during each spring runoff period. Only rarely in New England is a serious deficiency of ground water carried over from one year to the next. However, due to the lack of snowfall in the winter of 1964 - 1965, ground water recharge was incomplete, resulting in very low streamflows in the summer of 1965. In a total six-year period (1962 - 1967) the cummulative deficiency of runoff during the sixties drought varied from 30 inches in the southern part of the basin to over 35 inches in the north. These values are the equivalent of 1-1/2 years of normal runoff.

WATER

23. The Merrimack River is formed by the confluence of the Pemigewasset and Winnipesaukee Rivers at Franklin, New Hampshire. From this junction, it flows southerly for about 75 miles through New Hampshire and into Massachusetts. Just south of the state line, in the vicinity of Lowell, the river turns abruptly and flows generally northeasterly for about 45 miles to the Atlantic Ocean near Newburyport, Massachusetts, about 35 miles north of Boston. The lower 22 miles of the river are tidal. The mean tidal range is 8.3 feet at the Merrimack River mouth and 7.8 feet at the Newburyport wharves about 4 miles upstream. Mean spring range of tide is 9.5 feet.

24. The Pemigewasset River, the principal tributary of the Merrimack, in effect, constitutes an extension of the main river upstream from the confluence with the Winnipesaukee River at Franklin. The Pemigewasset descends 2,450 feet in its length of 64 miles, or an average of 34.6 feet per mile. Other tributary streams with drainage areas of 200 square miles or more are listed in the following table.

Table B-1. Major Tributaries of the Merrimack River

Tributary	Drainage Area (square miles)	Length (miles)
Baker*	213	28
Pemigewasset	1,021	64
Winnipesaukee	486	23
Contoocook	766	66
Suncook	260	39
Piscataquog	220	24
Souhegan	219	34
Nashua	530**	34
Concord	406***	16

*Tributary to the Pemigewasset River.

**Includes 117 square miles from which flow is diverted for water supply.

***Includes 93 square miles from which flow is diverted for water supply.

RESERVOIRS-LAKES-PONDS

25. The Merrimack River Basin has approximately 853,000 acre-feet of existing usable storage. Of this total, about 370,100 acre-feet are for flood control; about 273,800 acre-feet are used for power and recreation purposes and about 211,100 acre-feet are used as water supply reservoirs. The five major flood control reservoirs all operated by the Corps of Engineers in the basin are normally empty and their storage is used to store flood waters during periods of high rainfall and/or snowmelt runoff. The power and recreation storage is located generally in a few natural lakes, the most extensive of which is Lake Winnipesaukee (165,500 A.F.). In these lakes, regulation is dictated primarily by recreation needs and secondly, by the needs of downstream power plants. The majority of the water supply storage is located in Wachusett and Sudbury Reservoirs which supply consumers in the Boston Metropolitan region through interbasin transfers.

26. The Merrimack River estuary at Newburyport supports a sizable sport fishery. The most important fish species sought are striped bass, winter flounder, Atlantic mackerel, and pollock. Bait fish support a commercial fishery. Soft shell clams are abundant, but their utilization is limited by pollution. Schooners and ocean-going barges brought lumber, coal and building stone to the waterfront at Newburyport in a flourishing 19th century trade. However, after World War I, waterborne commerce in the harbor declined to insignificance. The current boom in recreational boating has revived the use of the harbor and its facilities, which consist chiefly of 20 commercial wharves, many in disrepair. Present use is for recreational craft dockings. The navigable reach of the river, between Newburyport and Haverhill, has recreational boat traffic and a few boatyards in operation. However, for quicker access to the ocean, most boat owners anchor their boats downstream in Newburyport Harbor rather than in the river.

HUMAN RESOURCES

27. Detailed information on human resources within the Merrimack River Basin is not generally gathered within the hydrologic boundaries of the basin itself. Data rather is compiled on an economic area basis. In addition, although this report is investigating future water supply needs within the Merrimack River Basin itself, a further charge of the study is to assess the basin's potential to meet long range needs within the eastern Massachusetts area. In order, then, to provide more meaningful entities for this report's planning, it became necessary to identify a set of economic regions for analysis. These regions, shown on Plate 3, encompass eight Standard Metropolitan Statistical Areas (SMSA's) within Massachusetts and two SMSA's within New Hampshire.

28. Similar social and economic traits, characterized by industrial divisions and locational analysis, were used to reduce the eight SMSA's in Massachusetts into four regions. These are Metropolitan Boston, Lawrence - Haverhill - Lowell, Worcester - Fitchburg - Leominster, and the Brockton - Fall River - New Bedford.

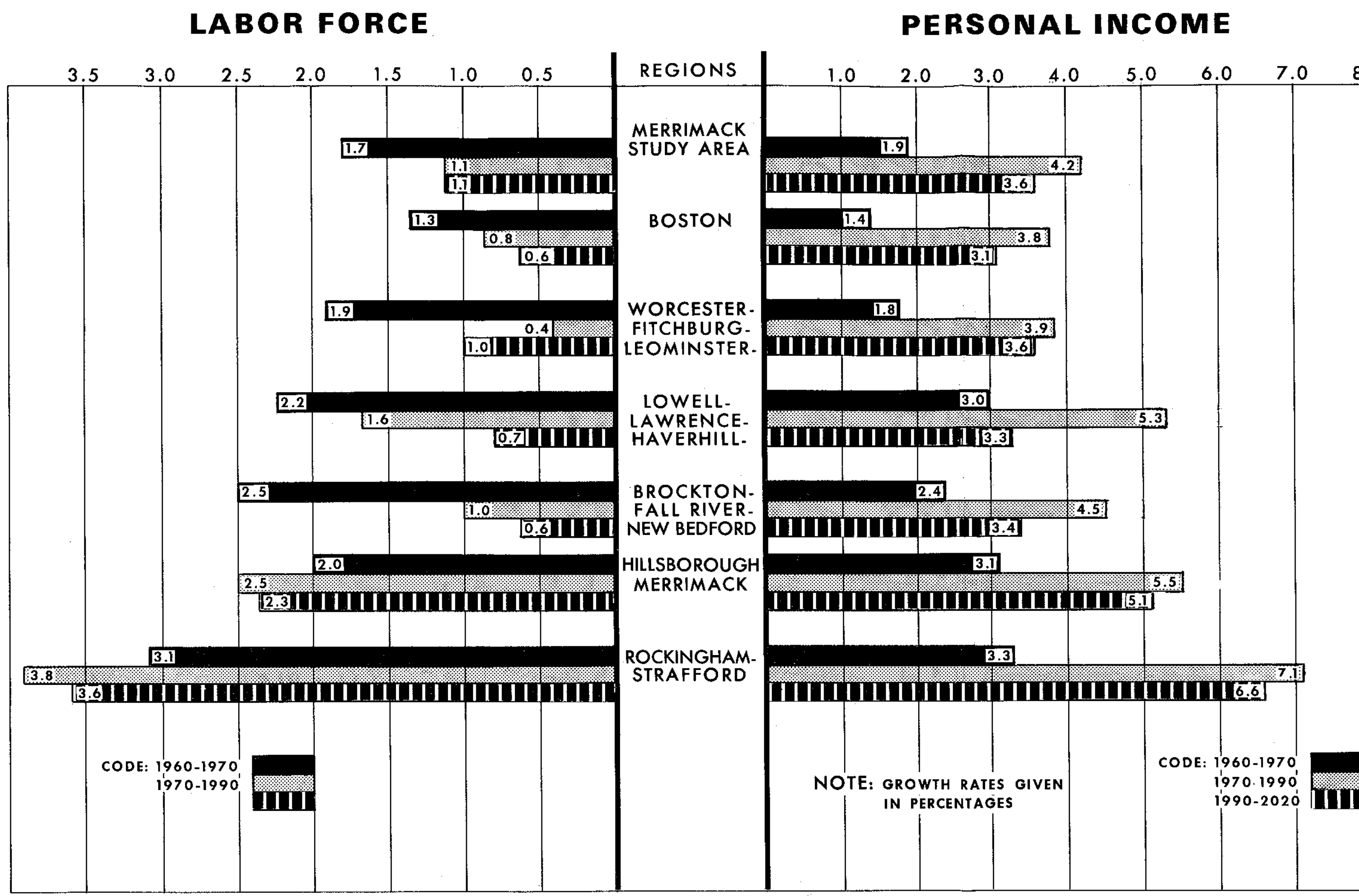
29. Within New Hampshire, Merrimack and Hillsborough Counties were linked into a single region which generally represents the New Hampshire portion of the basin. The two coastal counties of Strafford and Rockingham, possible service areas for water supplied, were incorporated into the sixth and final region considered in the study.

30. The aggregation of all six economic regions, i.e., four in Massachusetts and two in New Hampshire, was named the Merrimack River Economic Area. In the following paragraphs, descriptions are given of the Area's human resources and its current and projected economic conditions.

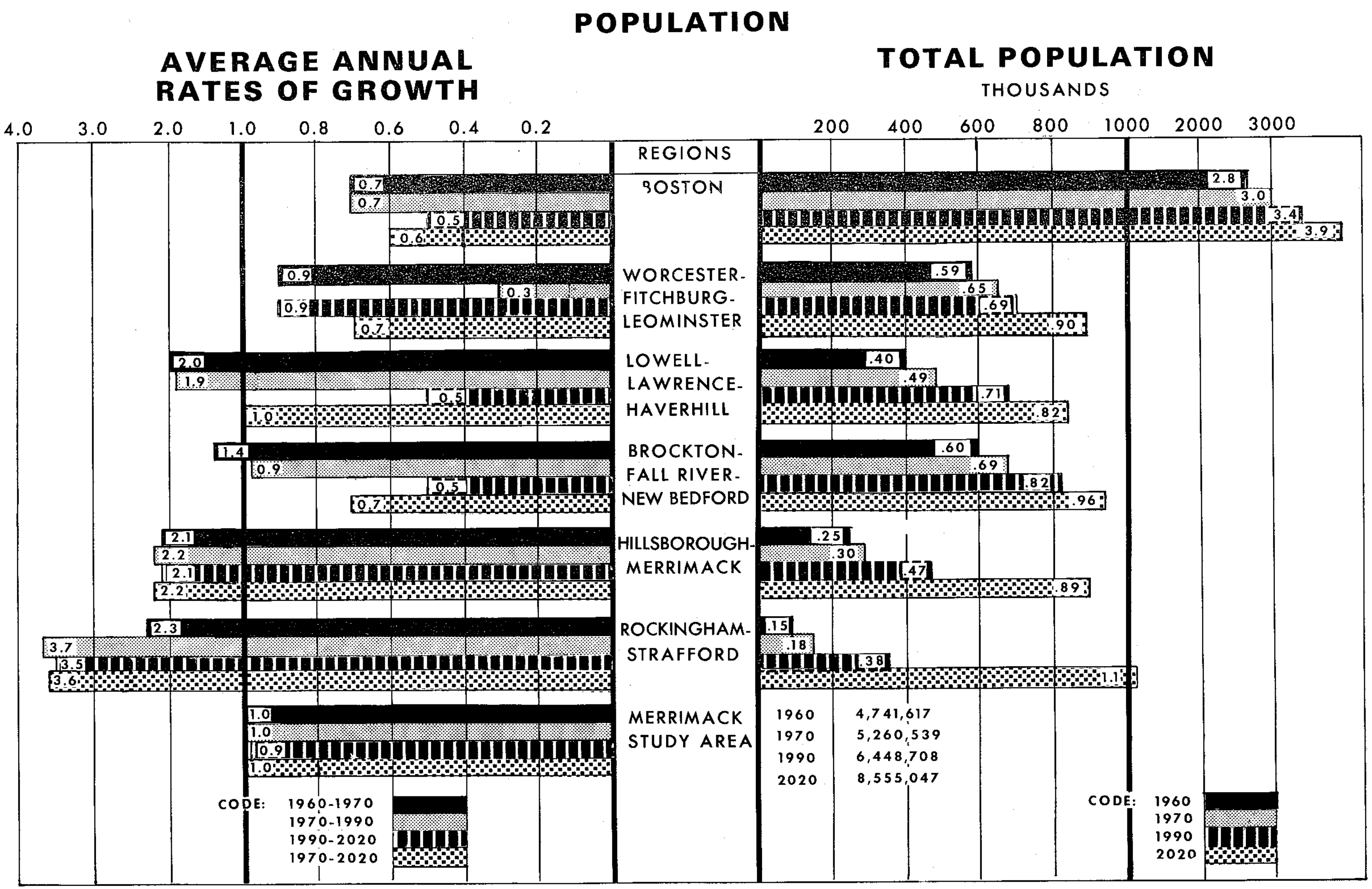
POPULATION CHARACTERISTICS

31. Population in the Merrimack River Economic Area increased by 11 percent between 1960 and 1970. As shown on Plate 4, the average annual rate of population growth ranged from 0.7 percent in the Boston Region to 2.3 percent in the less thickly settled regions of southern New Hampshire. Within the economic region, along the mainstem Merrimack River in Massachusetts, the rate of increase was recorded as 2.0 percent. Overall, during the decade from 1960 - 1970, the population growth in the central cities of the SMSA has been static. Only Brockton, Lowell and Nashua had gains greater than two percent. The remaining seven central cities either lost population or remained static. Data on total Population: United States, Massachusetts, New Hampshire, Merrimack River Economic Area, and Regions is given in Table B-2.

AVERAGE ANNUAL RATES OF GROWTH



NORTHEASTERN UNITED STATES WATER SUPPLY STUDY
MERRIMACK RIVER STUDY
ECONOMIC REGIONS
PROJECTED GROWTH RATES
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.



NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

MERRIMACK RIVER STUDY

ECONOMIC REGIONS
POPULATION GROWTH

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

Table B-2. Total Population: United States, Massachusetts, New Hampshire, Merrimack River Economic Area and Regions

Area	1960	1970	Average Annual Rates of Growth 1960 - 1970
United States	180,671,000	204,879,000	1.3
Massachusetts	5,148,578	5,689,170	1.0
New Hampshire	606,921	737,681	1.9
Merrimack River Economic Area	4,741,617	5,260,539	1.0
Boston Region	2,763,315	2,952,268	0.7
Worcester - Fitchburg Leominster Region	591,182	645,035	0.9
Lowell - Lawrence Haverhill Region	402,540	489,778	2.0
Brockton - Fall River New Bedford Region	593,350	685,984	1.4
Hillsborough - Merrimack Region	245,946	304,866	2.1
Rockingham - Strafford	145,284	182,608	2.3

MAJOR SKILLS AND OCCUPATIONS

32. Today the Merrimack River Economic Area is a part of the largest employment and population cluster in New England. This cluster is the northern terminus of "megalopolis," the Atlantic coastal strip between Washington and Boston. In the study area are eight SMSA's in Massachusetts and two mushrooming SMSA's in New Hampshire with a total of 5.3 million people in 1970. The cultural assets, most of the major universities, medical facilities, financial institutions, and library treasures are located in the Boston SMSA. Information on 1960 and 1970 employment by industry divisions for the nation, Massachusetts and New Hampshire, Merrimack River Economic Area is shown in Table B-3 and on Plate 5. Data on the various regions included within the Economic Area is given in Table B-4.

33. The share of the total labor force employed in manufacturing industries and per capita income is higher than the national average. The manufacturing activity is quite diversified with some specialization occuring in the individual cities and towns. The Area as a whole shows a degree of specialization in miscellaneous manufacturing. As shown on Plate 5, manufacturing as a whole in 1970 employed 28.1 percent of the total area employment. Wholesale and retail trade in turn employs 20.1 percent of the civilian labor force. The service base whose concentration is in the core city of Boston and adjacent communities, now accounts for the majority of total employment with 34.3 percent of the working population. Two conclusions can be drawn. First, although manufacturing employment in the study area is more concentrated than in the United States, its relative share of total employment has declined. This is due to the region's lack of natural resources, already high power costs and the decline of textile, leather and defense industries. Secondly, the service sector in the nation has grown 14 percent faster than that of the study area for the past decade. As heavy industry has relocated elsewhere, the study area has increasingly specialized in low bulk, high-technology, labor-intensive goods. It has also developed into a leading center for finance, education and medicine.

34. The Massachusetts and New Hampshire sectors of the Merrimack River Economic Area have different economic characteristics. Historically, Massachusetts has matured at the forefront of the United States transition from an agricultural to a manufacturing to a service based economy; in fact, it is a combination of a declining manufacturing industry and a growing service-base which characterize both the state and the study area today. Emphasizing this structural economic change is the declining non-durable manufacturing base which has not been fully offset by the growing durable sector.

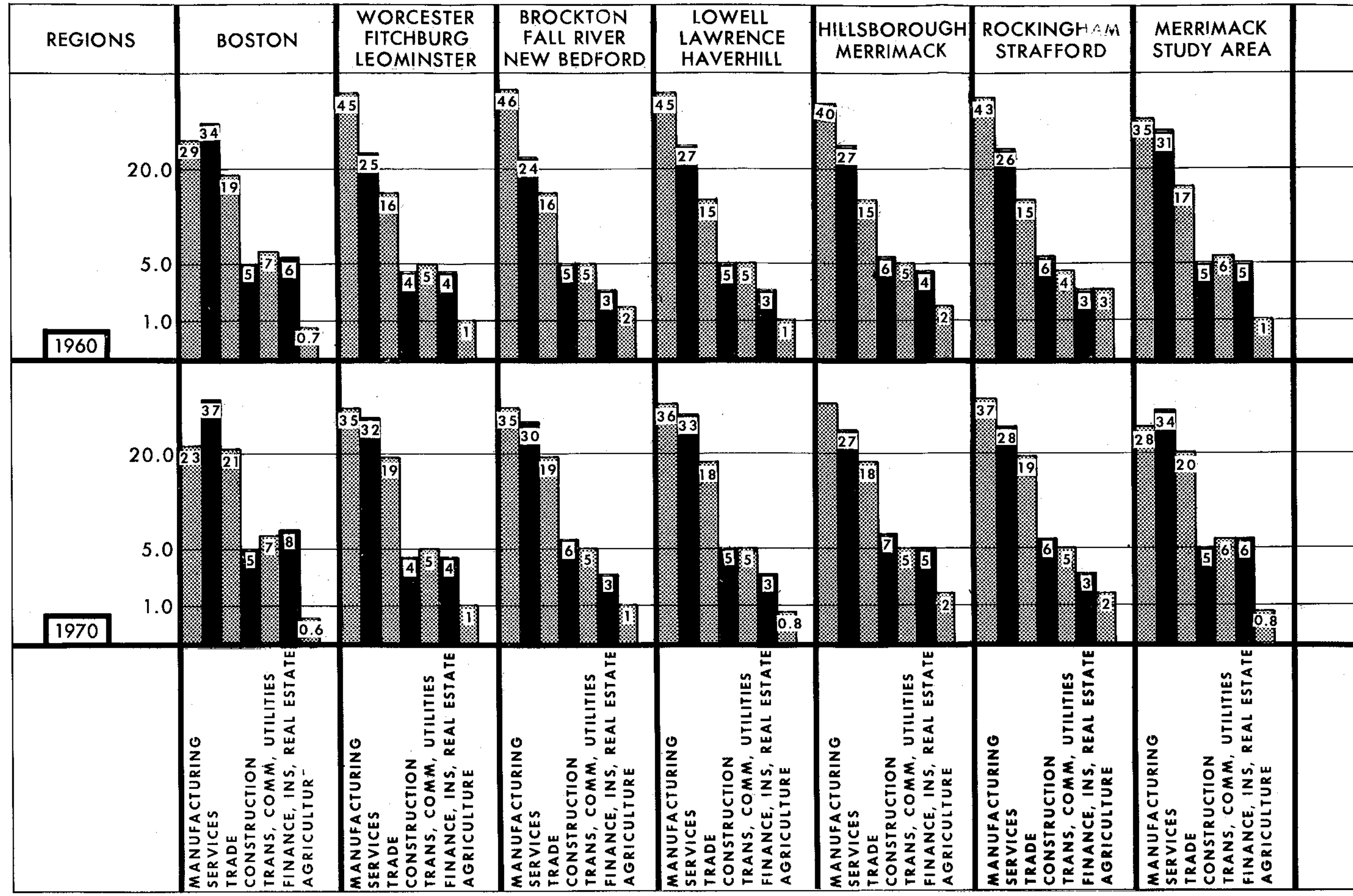
35. Today, with the extension of the East Coast "megalopolis" north of the Boston and Lowell SMSA's, the two regions in southern New Hampshire bear more of a resemblance to the heavily urbanized eastern Massachusetts than to the remainder of the rural agricultural state of New Hampshire. Although currently experiencing the same economic transformations as eastern Massachusetts did after World War II, the Hillsborough-Merrimack and Rockingham-Strafford regions can be characterized as less economically mature. This transformation into the durable commodities within the manufacturing base and into service-producing industries has not been fully completed in New Hampshire.

Table B-3

Employment by Industry Divisions: United States, Massachusetts, New Hampshire
Merrimack River Economic Area, and Regions, Selected Years
2A. Employment by Industry Divisions

	United States		Massachusetts		New Hampshire		Merrimack River Economic Area	
	1960	1970	1960	1970	1960	1970	1960	1970
Agriculture & Mining	5,144,287	3,304,553	27,354	21,430	7,487	5,595	18,786	17,184
Construction	3,968,253	4,219,249	99,823	112,332	13,501	18,873	82,865	102,499
Manufacturing	18,244,900	18,880,191	709,274	641,594	93,185	99,955	589,254	550,865
Trans., Comm., Public Utilities	4,650,643	4,906,111	115,464	125,363	10,803	12,745	100,223	115,897
Wholesale & Retail Trade	12,287,854	14,613,390	346,520	440,756	35,750	52,031	294,780	393,181
Finance, Insurance, and Real Estate	2,820,517	3,651,597	96,301	126,492	7,781	11,121	85,014	115,656
Service & Others	19,256,195	27,733,701	605,576	855,037	65,847	97,986	517,711	673,076
TOTALS	66,372,649	77,308,792	2,000,312	2,323,004	234,354	298,306	1,688,633	1,968,358
Goods-Producing Industries	27,357,440	26,403,993	836,451	775,356	114,173	124,423	690,905	670,548
Service-Producing Industries	39,015,209	50,904,799	1,163,861	1,547,648	120,181	173,883	997,728	1,297,810

PERCENTAGE DISTRIBUTION OF EMPLOYMENT



NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

MERRIMACK RIVER STUDY

ECONOMIC REGIONS

EMPLOYMENT IN MANUFACTURING

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

Table B-4

Employment by Industry Division

	Boston Region 1960	Boston Region 1970	Worcester Fitchburg Leominster Region 1960	Worcester Fitchburg Leominster Region 1970	Brockton Fall River New Bedford Region 1960	Brockton Fall River New Bedford Region 1970	Lowell Lawrence Haverhill Region 1960	Lowell Lawrence Haverhill Region 1970	Hillsborough Merrimack Region 1960	Hillsborough Merrimack Region 1970	Rockingham Strafford Region 1960	Rockingham Strafford Region 1970
Agriculture & Mining	7,901	7,186	1,835	1,949	3,409	3,122	1,575	1,443	2,281	1,981	1,785	1,503
Construction	51,603	57,780	6,994	9,439	9,027	12,841	6,403	8,696	5,535	8,604	3,303	5,139
Manufacturing	297,214	258,239	79,418	73,000	84,614	79,368	62,892	65,335	40,738	44,759	24,378	30,164
Trans., Comm., Public Utilities	68,933	75,541	8,393	10,233	9,050	12,223	6,557	8,035	4,847	5,995	2,443	3,870
Wholesale & Retail Trade	192,600	241,355	28,703	40,251	28,914	42,262	20,375	31,324	15,382	22,074	8,806	15,315
Finance, Insurance and Real Estate	63,121	85,789	6,723	8,783	5,531	6,627	3,902	5,704	4,187	6,128	1,550	2,635
Service & Others	351,467	422,559	43,066	68,223	44,042	67,622	36,691	58,420	27,285	33,739	15,160	22,513
TOTALS	1,029,839	1,148,449	175,132	211,878	184,587	224,065	138,395	178,957	100,255	123,280	57,425	81,139
Goods-Producing Industries	356,718	323,205	88,247	84,388	97,050	95,331	70,870	75,474	48,554	55,344	29,466	36,806
Service-Producing Industries	673,121	825,244	86,885	127,490	87,537	128,734	67,525	103,483	51,701	67,936	27,959	44,333

Table B-5. Personal Income: United States, Massachusetts, New Hampshire, Merrimack River Economic Area, and Regions, Selected Years
(In thousands of 1967 Constant Dollars)

Area	1960	1970	Average Annual Rates of Growth 1960 - 1970
United States	440,878,774	552,968,421	2.3
Per Capita	2,441	2,699	
Massachusetts	13,793,040	16,697,714	1.9
Per Capita	2,679	2,935	
Relative to U. S.	1.10	1.09	
New Hampshire	1,427,478	1,910,594	2.9
Per Capita	2,352	2,590	
Relative to U. S.	0.96	0.96	
Merrimack River Economic Area	13,314,778	16,029,794	1.9
Per Capita	2,808	3,047	
Relative to U. S.	1.15	1.13	
Relative to Mass.	1.05	1.04	
Relative to N. H.	1.19	1.18	
Boston Region	8,447,453	9,780,864	1.4
Per Capita	3,057	3,313	
Relative to U. S.	1.25	1.23	
Relative to Mass.	1.14	1.13	
Worcester, Fitchburg Leominster Region	1,456,672	1,741,595	1.8
Per Capita	2,464	2,700	
Relative to U. S.	1.01	1.00	
Relative to Mass.	0.92	0.92	
Lowell, Lawrence, Haverhill Region	1,021,647	1,368,468	3.0
Per Capita	2,538	2,794	
Relative to U. S.	1.04	1.04	
Relative to Mass.	0.95	0.95	

Table B-5 (Cont'd)

Area	1960	1970	Average Annual Rates of Growth 1960 - 1970
Brockton, Fall River New Bedford Region	1,438,874	1,839,123	2.4
Per Capita	2,425	2,681	
Relative to U. S.	0.99	1.00	
Relative to Mass.	0.91	0.91	
Hillsborough, Merrimack Region	605,519	823,138	3.1
Per Capita	2,462	2,700	
Relative to U. S.	1.01	1.00	
Relative to N. H.	1.05	1.04	
Rockingham, Strafford Region	344,613	476,606	3.3
Per Capita	2,372	2,610	
Relative to U. S.	0.97	0.97	
Relative to N. H.	1.00	1.00	

36. Almost 300,000 jobs were added to the employment roles of the study area during the 1960's. The 16 percent gain was comparable to both Massachusetts and the nation. Manufacturing employment experienced a relative and absolute decline which, because of the industry's preponderance in the Merrimack River Economic Area, resulted in large employment lags with over 40,000 jobs being lost. The share of service-producing industries grew and the goods-producing industries lost ground. The substantial growth of employment in the durable producing industries was offset by larger losses in the non-durables industries such as textiles, apparel, leather, and food. However, the shift of employment within the manufacturing sector toward the more rapidly growing durables resulted in a more favorable industry-mix by 1973. Nevertheless, the study area cannot continue to expand with the service sector alone; it must nurture the developing durable base in order to maintain its economic growth. These are the kinds of jobs that "drive" the regional economy and generate substantial multiplier effects through linkages to other employment opportunities.

PERSONAL INCOME

37. Per capita income is an excellent measure of regional wealth and economic well being. In both 1960 and 1970, the Merrimack River Economic Area's per capita income has been greater than that of the two states and the nation. As shown in Table B-5, the index of per capita income averaged 114 percent for the years 1960 and 1970. Within the Economic Area, itself, however, there is a wide range of personal income levels. For example, the Boston region with an index of 123 percent is by far the Area's highest income level. The Rockingham-Strafford region within New Hampshire, on the other hand, only records a value of 97 percent.

DEVELOPMENT AND ECONOMY

38. The following paragraphs present a summary of projected economic conditions in the Merrimack River Economic Area which are necessary for assessing coordinated water supply management programs for the future.

MEASURES OF ECONOMIC ACTIVITY

39. Economic changes can be measured by a set of interrelated variables such as population, labor force, employment, personal income and net output. These indicators express in economic terms the need for water resource development in an area. Especially important are the numbers of people projected to live in an area and any expected changes in industrial activity.

40. National projections of the overall economy were made in terms of aggregates such as gross national product, population, personal income and employment. From these summary measures was derived information for local areas. Implicit in this procedure is the fact that national forces clearly dominate economic growth throughout the nation. Because of the lack of gross area product data which could be compared to gross national product data, other indicators of economic activity at the regional level are utilized. Employment data, available in detail at the regional level, are used to indicate changes in industrial activity; and total personal income provides an overall measure of regional growth.

PROJECTED POPULATION, EMPLOYMENT AND INCOME

41. Population projections developed for the Massachusetts Office of State Planning and for the Division of Economic Development, Department of Resources and Economic Development, State of New Hampshire were adopted for use by this study. These projections represent in essence the states view of how the cities and towns within their boundaries will grow.

42. A comparison of the respective state population projections to those Series E figures published by the United States Water Resources

Council (WRC) was made to determine the relationship between the projections. The Massachusetts projections compare quite favorably with the WRC projections with only minor differences found even through the long range (2020) target year. For New Hampshire, the over-all population estimates prepared by the state are much higher than the WRC projections because of more recent evidence of greater strength in that State's economy.

43. The average annual rate of population growth as shown on Table B-6, Economic Area, established during the 1960's is expected to continue throughout the next fifty years and follow national trends. In the 1970 - 2020 projection period, population for the economic area as presented in Table B-7 should increase 63 percent. However, population growth rates in Massachusetts are projected to be somewhat lower and this contrasts sharply with that of New Hampshire which is expected to increase three-fold during the entire period at a compound rate of 2.4 percent per year.

44. The study area's share of United States population reflects a minor loss; but compared to both states in which the area lies, the population distribution given in Table B-8 will be generally constant. Area population density will rise more rapidly than that of the state of Massachusetts and gain support from the strength in the two New Hampshire regions. The latter state's growth appears to be based on its natural increase, its inherent attractiveness, and in particular the "spillover" from the Boston Core City with primary emphasis on the urbanized strip along the lower Merrimack River. In the future, all three factors are expected to continue.

45. The labor force growth is expected to follow a pattern similar to the population forecast. With a projected slowing of the growth rate, one might expect the labor force to grow less rapidly because a large number of persons born in the baby boom years of the late 1940's have been already fully absorbed into the labor market. From 1970 - 1990, the civilian labor force in the study area is projected to increase 23 percent at an average annual rate of growth of 1.1 percent. This increase shown on Tables B-9, B-10 and B-11 is 6 percent more than that for the State of Massachusetts but falls slightly short of the national figure. With a projected decline in the unemployment rate of one full percent from 1970 to 1990, the study area as a whole should experience an expanding economy for the period. As the New Hampshire labor force participation rate gradually moves higher, it should close the gap between its neighboring

Table B-6

Total Population: United States, Massachusetts, New Hampshire, Merrimack River Economic Area and Regions, Selected Years

	1960	1970	1990	2020
United States	180,671,000	204,879,000	258,692,000	351,368,000
Massachusetts	5,184,578	5,689,170	6,640,100	7,979,400
New Hampshire	606,921	737,681	1,166,800	2,384,000
Merrimack River Economic Area	4,741,617	5,260,539	6,448,708	8,555,047
Boston Region	2,763,315	2,952,268	3,384,958	3,925,243
Worcester-Fitchburg-Leominster Region	591,182	645,035	687,004	895,124
Lowell-Lawrence-Haverhill Region	402,540	489,778	707,300	818,200
Brockton-Fall River-New Bedford Region	593,350	685,984	823,906	962,780
Hillsborough-Merrimack Region	245,946	304,866	468,400	887,600
Rockingham-Strafford Region	145,284	182,608	377,100	1,066,100

Table B-7

Average Annual Rates of Population Growth, Selected Years

	1960-1970	1970-1990	1990-2020	1970-2020
United States	1.3	1.2	1.0	1.1
Massachusetts	1.0	0.8	0.6	0.7
New Hampshire	1.9	2.3	2.4	2.4
Merrimack River Economic Area	1.0	1.0	0.9	1.0
Boston Region	0.7	0.7	0.5	0.6
Worcester-Fitchburg-Leominster Region	0.9	0.3	0.9	0.7
Lowell-Lawrence-Haverhill Region	2.0	1.9	0.5	1.0
Brockton-Fall River-New Bedford Region	1.4	0.9	0.5	0.7
Hillsborough-Merrimack Region	2.1	2.2	2.1	2.2
Rockingham-Strafford Region	2.3	3.7	3.5	3.6

Table B-8

Study Area's Population as a Percent of United States, and Massachusetts and New Hampshire

	1960	1970	1990	2020
Percent of United States Population	2.62	2.57	2.49	2.44
of Massachusetts and New Hampshire	82.4	81.9	82.6	82.6

Region Populations as Percent of Area Population

	1960	1970	1990	2020
Boston Region	58.3	56.1	52.5	45.9
Worcester-Fitchburg-Leominster Region	12.5	12.3	10.7	10.5
Lowell-Lawrence-Haverhill Region	08.4	09.3	11.0	9.6
Brockton-Fall River-New Bedford Region	12.5	13.0	12.8	11.3
Hillsborough-Merrimack Region	05.2	5.8	07.2	10.4
Rockingham-Strafford Region	03.0	3.5	05.8	12.5
Area	100.0	100.0	100.0	100.0

Table B-9

Total Civilian Labor Force: United States, Massachusetts, New Hampshire, Merrimack River Basin Economic Area, and Regions, Selected Years

	1960	1970	1990	2020
United States	72,104,000	85,903,000	109,550,000	148,720,000
Massachusetts	2,129,285	2,444,926	2,888,432	3,590,747
New Hampshire	251,309	313,465	507,558	1,072,800
Merrimack River Economic Area	1,925,933	2,278,647	2,812,569	3,860,663
Boston Region	1,132,262	1,288,490	1,492,766	1,789,910
Worcester-Fitchburg-Leominster Region	233,580	281,706	303,673	409,071
Lowell-Lawrence-Haverhill Region	168,872	209,599	289,228	358,576
Brockton-Fall River-NewBedford Region	232,436	297,652	361,694	437,102
Hillsborough-Merrimack Region	104,783	127,800	209,843	411,846
Rockingham-Strafford Region	54,000	73,400	155,365	454,158

Table B-10

Average Annual Rates of Labor Force Growth, Selected Years

	1960-70	1970-90	1990-2020	1970-2020
United States	1.8	1.2	1.0	1.1
Massachusetts	1.4	0.8	0.7	0.8
New Hampshire	2.3	2.4	2.5	2.5
Merrimack River Economic Area	1.7	1.1	1.1	1.1
Boston Region	1.3	0.8	0.6	0.7
Worcester-Fitchburg-Leominster Region	1.9	0.4	1.0	0.8
Lowell-Lawrence-Haverhill Region	2.2	1.6	0.7	1.1
Brockton-Fall River-New Bedford Region	2.5	1.0	0.6	0.8
Hillsborough-Merrimack Region	2.0	2.5	2.3	2.4
Rockingham-Strafford Region	3.1	3.8	3.6	3.7

Table B-11

Regional Labor Force as a Percent of Area

	1960	1970	1990	2020
Boston Region	58.8	56.6	53.1	46.4
Worcester-Fitchburg-Leominster Region	12.1	12.4	10.8	10.6
Lowell-Lawrence-Haverhill Region	8.8	9.2	10.3	9.3
Brockton-Fall River-New Bedford Region	12.0	13.1	12.9	11.3
Hillsborough-Merrimack Region	5.4	5.6	7.5	10.7
Rockingham-Strafford Region	2.8	3.2	5.5	11.6
AREA	100.0	100.0	100.0	100.0

state and the Merrimack River Area which for all practical purposes will be equal by 1990. Both states and the Merrimack Area will have a larger proportion of the population in the labor force than will exist on the national level. This is due to the higher educational levels in this region and to the traditional reliance of the textile industry, and more recently the electronics and service industries, on female workers. Higher participation rates and lower unemployment rates will enable the Area to utilize more of its resources for economic growth.

46. Change occurs with economic progress. After the discretionary fiscal policy measures of 1964 which altered the tax structure, an economic boom occurred in the mid and late 1960's. Labor force participation rates increased and unemployment rates declined. Total employment from 1960 - 1970 increased by 16 percent, not only in the Merrimack River Area, but also in both Massachusetts and the nation. Although no statistical projections have been made to assist with future forecasting of employment sectors, some insight can still be obtained from trend movements over the past 20 years. From 1950 to the present, the predominant nondurable manufacturing sector has been declining. Although there have been sharp advances in durable goods, the overall rate of growth of Massachusetts has lagged behind the rest of the country. The Massachusetts share of national manufacturing employment fell from 4.70 percent in 1950 to 3.15 percent in 1971. The decline of manufacturing employment is distributed over all SMSA's in the state.* In one recent twelve month period, the following declines were recorded:

Worcester	10.5%
Brockton	7.4%
Lowell	7.2%
State Average	5.8%
Lawrence, Haverhill	5.5%
Boston	5.4%
New Bedford	5.0%
Fall River	4.6%

As a consequence, the Massachusetts unemployment rate for the past five years has risen well above the national average, and the total manufacturing employment index for Massachusetts, with 1967 = 100 as the base, reached a low of 82 in February 1975.

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* In the absence of comparable data on the specified regions in this study, information of SMSA's will be used.

Unemployment Rates

Feb 75		1974	1973	1972	1971	1970
8.2	United States	5.6	4.9	5.6	6.0	5.0
11.0	Massachusetts	8.1	6.9	7.2	7.0	5.1
6.1	New Hampshire	4.9	3.9	4.5	4.9	3.5
10.8	1. Boston	7.6	6.2	5.9	5.8	4.3
9.8	2. Worcester	7.6	6.1	7.2	7.2	4.9
14.2	3. New Bedford	9.1	6.5	5.9	8.9	9.0
6.1	4. Manchester	4.7	3.8	4.4	4.7	3.7

Total Manufacturing Employment (1967 = 100)

	High	Low	Current (Feb 75)
United States	1973 = 100	Feb 1975 = 93	93
Massachusetts	1970 = 98	Feb 1975 = 82	82
New Hampshire	1970 = 99	1971 = 86	90

47. On the other hand, through 1974, the New Hampshire unemployment rate has remained at least one full point below the national average and its index for total manufacturing employment is currently at 90. The Massachusetts decline has been much more severe. Whether this short five year cyclical trend in unemployment rates will develop into a secular movement is questionable. Since the Merrimack Economic Area is an economically mature region, it is unlikely that there will be sufficient inherent growth strength in the existing industrial base to close this employment gap.

48. A substantial part of Massachusetts manufacturing has been concentrated in the non-durable industries of food, textiles, apparel and leather. These four traditional exporting industries, which have undergone a long-term deterioration have produced a persistent drag on employment. Furthermore, three major growth sectors over the last decade (i.e. services, construction, and research and development) have outlived their initial growth capacity and will no longer provide the large part of the much needed job opportunities. The key problem in a mature economy is not only to find a way to improve industrial management, output, and productivity, but also to replace lagging industries with new growth industries.

49. Two conclusions can be drawn. Many industries in the existing economic base of the Merrimack Study Area are technologically efficient and are expected to expand rapidly in the state and nation through 1990. Electrical equipment and supplies, nonelectrical machinery, chemicals, transportation equipment, and instruments could make a positive contribution to the revitalization of the durable manufacturing component in the study area economy. Four of the above five with the exclusion of instruments have lagging national growth rates. Only chemicals is a major water using industry. Secondly, there is a group of both technologically efficient and import-substitute industries which have minimal concentration and could serve a much greater market in the area. Import-substitute industries exist when a part of total area demand is unfilled by the output of existing area manufacturing firms. These industries are lumber and wood products, furniture and fixtures, printing and publishing, paper and allied goods which is a major water using industry, and fabricated metals.

50. Special emphasis has centered on the declining employment in manufacturing. Success or failure of the Merrimack River Economic Area will rest on changes made here. What industries will propel the economic expansion in the next 50 years is difficult to forecast. However, one definite conclusion of primary importance can be drawn and emphasized with respect to four of the six major water using industries. Food along with textiles, apparel, and leather will be unattractive routes of revitalization. Growth over the next two decades in these industries is expected to be very slow. On the other hand, both the industries of paper and chemicals provide viable employment and production alternatives. The Merrimack River Economic Area cannot continue to grow with the service-producing industries alone. It is true that services do stimulate growth. However, the smaller secondary job effects through the linkage procedure and lower productivity make complete reliance on services an unattractive choice. Only time will tell whether the manufacturing share of employment will be substantially different from the trends established during the decade of the 1960's.

51. Total personal income as shown in Table B-12 in the Merrimack Area is projected to grow basically at the same rate as that in the state of Massachusetts and the nation over the next 50 years. This can be attributed to the recent steep decline in the non-durable component of manufacturing which has not been sufficiently offset by the sharp advance in durables and the service-producing industries. The area's income is expected to increase from $16,029,794 in 1970

to approximately $107,512,000 in 2020, rising by a factor of 6.5 in comparison to the national change of 7.8. Given the initial assumption that the area's change in personal income will converge toward the national average, the Merrimack's share of national income will fall from 3.0 to 2.5 percent.

52. With population in the study area projected to increase by a factor of 1.6 and personal income by 6.5, by 2020 per capita income will increase over fourfold; by 1990 it will almost double. From a high of 1.15 in 1960, the index for per capita income relative to the United States is expected to decline to 1.03 in 2020. This projection is based on a gradual economic maturing of more recently developed sections of the country and somewhat lowering of regional differences in economic opportunity.

53. In summary, the average annual rate of growth of both the population and the labor force over the next 50 years for the Merrimack River Area will be equivalent to the United States and slightly higher than that of Massachusetts. Since the recent economic growth of New Hampshire has been faster than Massachusetts, the next 20 and 50 years will be a period of rapid development as the East Coast "megalopolis" extends further into this state. As the composition of employment has changed over the past 20 years within the goods-producing industries and between the latter and the service-producing industries, the area's past high growth in personal income has slightly lagged behind national movements. The increasing service-producing industries strength in the region has raised problems of slower income growth, decreasing productivity, less investment in capital equipment, and erosion of future growth potential in manufacturing which has a higher multiplier effect after the initial outlay of capital stock. Industrial changes are expected to occur which should produce increased employment in the technically efficient industries and those with rapid expansion at both the state and national level. Then, the relationships in personal income between the Merrimack River Economic Area and the United States could improve for the benefit of the study area.

Table B-12

Personal Income: United States, Massachusetts, New Hampshire, Merrimack River Economic Area, and Regions, Selected Years
(In thousands of 1967 Constant Dollars)
Total Personal and Per Capita Income

	1960	1970	1990	2020
United States	440,878,774	552,968,421	1,371,584,984	4,308,123,048
Per Capita	2,441	2,699	5,302	12,261
Massachusetts	13,793,040	16,697,714	37,370,483	99,830,273
Per Capita	2,679	2,935	5,628	12,511
Relative to U.S.	1.10	1.09	1.06	1.02
New Hampshire	1,427,478	1,910,594	5,853,836	29,008,512
Per Capita	2,352	2,590	5,017	12,168
Relative to U.S.	0.96	0.96	0.95	0.99

Table B-12 (Cont'd)

	1960	1970	1990	2020
Merrimack River Economic Area	13,314,778	16,029,794	36,658,591	107,512,545
Per Capita	2,808	3,047	5,685	12,567
Relative to U.S.	1.15	1.13	1.07	1.03
Relative to Mass.	1.05	1.04	1.01	1.00
Relative to N.H.	1.19	1.18	1.13	1.03
Boston Region	8,447,453	9,780,864	20,330,057	50,592,457
Per Capita	3,057	3,313	6,006	12,889
Relative to U.S.	1.25	1.23	1.13	1.05
Relative to Mass.	1.14	1.13	1.07	1.03

Table B-12 (Cont'd)

	1960	1970	1990	2020
Worcester, Fitchburg, Leominster Region	1,456,672	1,741,595	3,718,969	11,006,445
Per Capita	2,464	2,700	5,413	12,296
Relative to U.S.	1.01	1.00	1.02	1.00
Relative to Mass.	0.92	0.92	0.96	0.98
Lowell, Lawrence, Haverhill Region	1,021,647	1,368,468	3,880,955	10,121,134
Per Capita	2,538	2,794	5,487	12,370
Relative to U.S.	1.04	1.04	1.03	1.01
Relative to Mass.	0.95	0.95	0.97	0.99

Table B-12 (Cont'd)

	1960	1970	1990	2020
Brockton-Fall River-New Bedford Region	1,438,874	1,839,123	4,427,670	11,900,930
Per Capita	2,425	2,681	5,374	12,257
Relative to U.S.	0.99	1.00	1.01	1.00
Relative to Mass.	0.91	0.91	0.95	0.98
Hillsborough-Merrimack Region	605,519	823,138	2,401,487	10,897,952
Per Capita	2,462	2,700	5,127	12,278
Relative to U.S.	1.01	1.00	0.97	1.00
Relative to N.H.	1.05	1.04	1.02	1.01
Rockingham-Strafford Region	344,613	476,606	1,899,453	12,993,627
Per Capita	2,372	2,610	5,037	12,188
Relative to U.S.	0.97	0.97	0.95	0.99
Relative to N.H.	1.00	1.00	1.00	1.00

Table B-13

Average Annual Rates of Growth of Personal Income

	1960-1970	1970-1990	1990-2020	1970-2020
United States	2.3	4.6	3.9	4.2
Massachusetts	1.9	4.1	3.3	3.6
New Hampshire	2.9	5.8	5.5	5.6
Merrimack River Economic Area	1.9	4.2	3.6	3.9
Boston Region	1.4	3.8	3.1	3.3
Worcester-Fitchburg-Leominster Region	1.8	3.9	3.6	3.8
Lowell-Lawrence-Haverhill Region	3.0	5.3	3.3	4.0
Brockton-Fall River-New Bedford Region	2.4	4.5	3.4	3.8
Hillsborough-Merrimack Region	3.1	5.5	5.1	5.3
Rockingham-Strafford Region	3.3	7.1	6.6	6.7

SECTION C

PROBLEMS AND NEEDS

1. This section describes the problems and needs which were investigated during the conduct of the study. The drought of the sixties and its impact on the region's water supplies are discussed. Since the Merrimack River Basin may have potential for serving the water supply needs of out-of-basin metropolitan regions, the role which the Merrimack may play in meeting the longer range overall region's needs is also presented. Other water resource needs within the Merrimack, such as water quality improvement, riparian rights, and the proposed anadromous fish restoration, as related to the use of the river as a water supply are also described. Improvements desired as expressed by local interests at progress and public meetings are also discussed.

DROUGHT OF THE SIXTIES

2. As recognized in the NEWS legislation, natural departures from "normal" precipitation and runoff conditions can have regional impacts on the social well-being of a large segment of the nation's population. The "normal" condition which is actually the average of many high and low rainfall years is approximately 42 inches of rainfall per year in southeastern New England. When rainfall is below average for a period of time, the area experiences a drought. The recent drought of the sixties in Southeastern New England, for its duration, was the severest ever experienced in the region, based on over two hundred years of rainfall record.

3. The severity of the situation was caused by the combination of two factors -- a severe hydrologic adversity and the centering of the drought on the most densely populated region of the United States.

The drought began in 1961 and continued for seven years, with the greatest deficiency occurring in 1965. During this period, an extreme drought condition existed in the northern half of New Jersey, northeast Pennsylvania, southeastern New York, all of Vermont and New Hampshire, parts of southern Maine and the western half of Massachusetts.

4. In Massachusetts, at the height of the drought, 85 cities and towns, including the two million customers of the MDC, were asked to institute voluntary water rationing programs. Of these 85 communities, 23 required emergency sources of water, which are sanctioned by the Department of Public Health for temporary use only. Because of the severity of the drought, many water supply systems were required to re-evaluate the dependable yield which their facilities could be relied on to produce. The MDC, for example, which had estimated its available sources at 330 mgd based on previous drought data, revised their dependable yield figure downward to 300 mgd.

5. In addition to affecting the water use patterns of approximately 20 million people, the drought also had a severe impact on the environment. Low stream flow intensified pollution problems, affecting water quality and fish and wildlife. Algae blooms caused problems of taste and odor in water supplies and interfered with recreational use of lakes and reservoirs. The prolonged sixties' drought thus caused extensive hardships on man and his environment. Fortunately, the years preceding the drought were abnormally "wet" years. These "wet" years allowed many of the region's water supply reservoirs to enter the drought period in a filled condition, precluding even more severe water use restrictions. There is no assurance, however, that the next drought, whenever it may occur, will be preceded by aquifer and reservoir filling "wet" years.

EXISTING WATER SUPPLY SYSTEMS

6. Public* water supply systems within the Merrimack River Basin furnished the supply needs of about 1.2 million or approximately 80 percent of the basin's 1970 population. A total of 95 systems were reported with populations served varying from 140 to over 100,000. Fifty-seven systems supplied population centers of over 5,000 persons, and data on these facilities are shown in Table C-1. Water supply systems for communities with populations of 30,000 or more are detailed in the following paragraphs and shown on Plate 6.

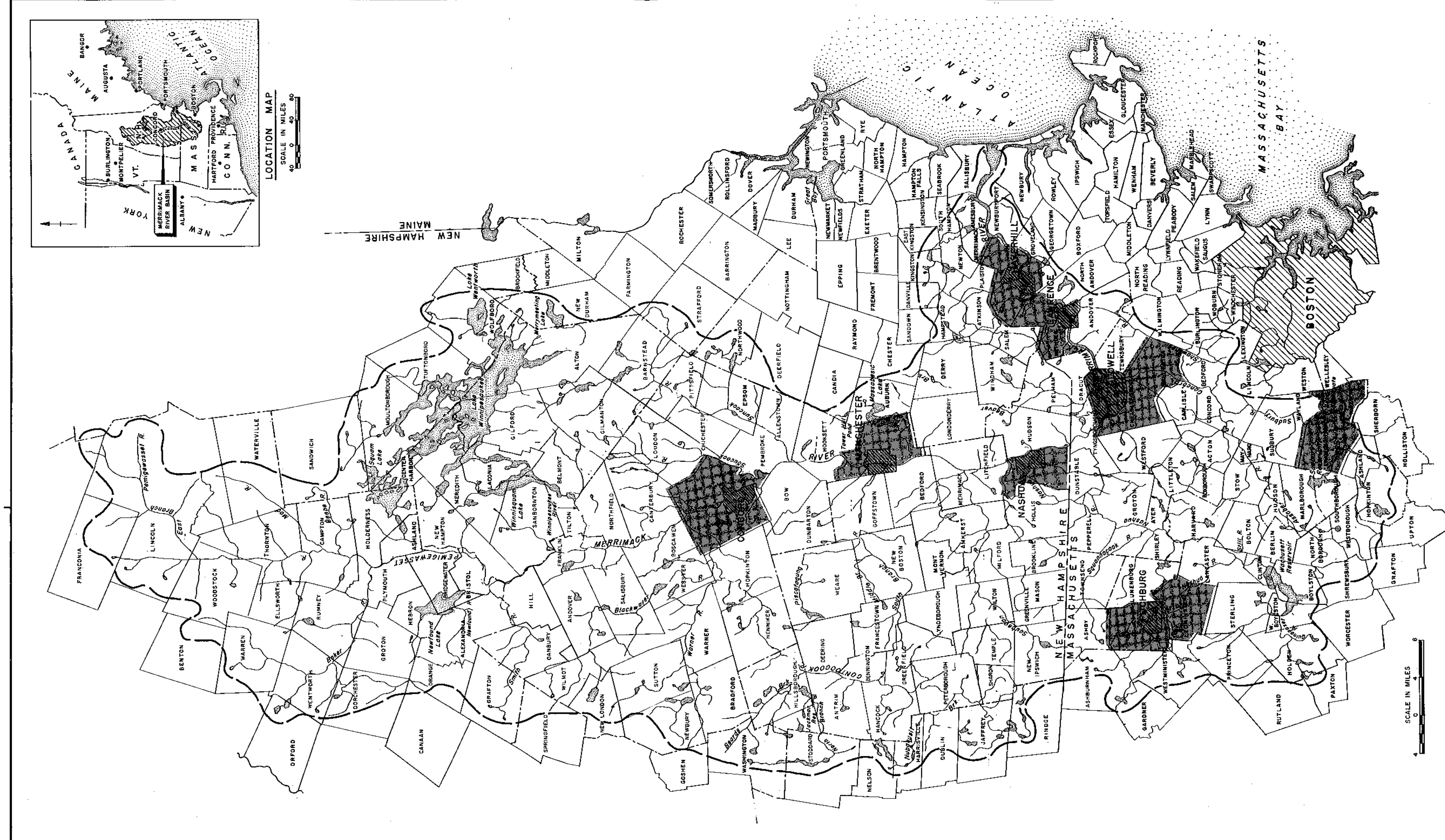
MASSACHUSETTS

7. Billerica: Billerica is located 20 miles northwest of Boston in the Lowell metropolitan area. In 1970, the population of the town was 31,284, a 75% increase over its 1960 population figure. The municipal water department services an estimated 93 percent of the town's citizens through a system which is 100 percent metered. The system supplied an average daily demand of 2.65 mgd in 1970. The history of the Billerica water system dates back to 1897 when the Massachusetts Legislature authorized the Town to take water "for the purpose of supplying itself and its inhabitants with water for the extinguishment of fires and for domestic and other purposes." Following this legislation, the town constructed supply facilities utilizing ground water wells. Deteriorating water quality in the form of increased iron and manganese concentrations plagued the initial wellfield and subsequent fields which were developed up to 1956. In 1956, the town constructed a 3.5 mgd water treatment plant which used the Concord River, a tributary of the Merrimack, as its supply source. At this time, the well supply was relegated to an emergency use only status. In 1963, the plant's capacity was increased to 7.0 mgd. The treatment consists of breakpoint chlorination, chemical coagulation, sedimentation, rapid sand filtration and the addition of activated carbon. At present, an expansion of the treatment plant to 14.0 mgd is under way.

*Public systems refer to both municipally and private investor owned facilities.

Table C-1. Existing Municipal Water Supplies[1] in the Merrimack River Basin

Municipal System	1970 Total Population	1970 Average Demand (mgd)	Present Source	Present[2] Dependable Yield (mgd)
Massachusetts				
Acton	14,578	1.08	Wells	2.75
Amesbury	11,388	0.97	Wells	3.00
Andover	23,695	3.20	Haggetts Pond	14.50
Ashland	8,900	1.33	Wells	4.36
Ayer	8,300	0.85	Wells	1.50
Bedford	13,473	1.58	Wells	3.30
Billerica	31,648	2.65	Concord River	14.00
Chelmsford	31,432	2.36	Wells	5.80
Clinton[3]	13,270	0.86	Wachusett Reservoir	N/A[4]
Concord	15,971	1.78	Ponds & Wells	5.50
Dracut	18,214	1.06	Wells	2.70
Fitchburg	42,906	7.90	Reservoirs	11.90
Framingham[3]	63,233	7.15	Wells	2.13
Gardner	19,750	1.63	Reservoirs	1.78
Georgetown	5,290	0.43	Wells	1.40
Groton	5,100	0.82	Wells	1.51
Groveland	5,382	0.55	Well	1.30
Haverhill	46,120	6.20	Lakes & Ponds	8.75
Holden	12,564	1.26	Ponds & Wells	1.02
Hopkinton	6,000	0.45	Wells	1.30
Hudson	15,853	1.35	Ponds & Wells	2.52
Lancaster	6,100	0.49	Wells	1.00
Lawrence	66,915	10.00	Merrimack River	14.00
Leominster[3]	32,709	8.07	Reservoirs & Wells	7.25
Littleton	6,400	0.66	Wells	1.80
Lowell	94,239	10.00	Merrimack River	10.50



NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

MERRIMACK RIVER STUDY

MAJOR WATER SUPPLY SYSTEMS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

Table C-1 (Cont'd) Existing Municipal Water Supplies [1]
in the Merrimack River Basin

Municipal System	1970 Total Population	1970 Average Demand (mgd)	Present Source	Present[2] Dependable Yield (mgd)
Massachusetts (cont'd)				
Lunenburg	7,400	0.28	Wells	0.75
Marlborough[3]	27,721	2.41	Lake & Reservoir	5.58
Maynard	9,551	0.75	Ponds & Wells	1.04
Methuen	35,456	2.80	Merrimack River[5]	N/A
Natick	31,055	6.50	Wells	10.16
Newburyport	15,807	2.15	Reservoirs & Wells	3.35
North Andover	16,284	1.88	Lake Cochituate	3.00
Northborough[3]	9,253	0.70	Wells	0.95
Pepperell	5,887	0.54	Wells	1.70
Shrewsbury	19,229	1.60	Wells	2.90
Southborough	5,800	0.44	MDC Hultman Aqueduct	N/A
Sudbury	13,508	1.12	Wells	3.70
Tewksbury	22,755	1.87	Wells	3.30
Wayland	13,588	1.58	Wells	5.58
Westborough	12,438	1.01	Ponds & Wells	1.99
West Boylston	6,400	0.48	Wells & Worcester	2.05
Westford	10,368	0.62	Wells	4.80
TOTALS	881,930	101.39		176.42

Table C-1 (Cont'd) Existing Municipal Water Supplies [1] in the Merrimack River Basin

Municipal System	1970 Total Population	1970 Average Demand (mgd)	Present Source	Present[2] Dependable Yield (mgd)
New Hampshire				
Bedford	5,900	1.10	Lake Massabesic	N/A[6]
Concord	30,020	4.10	Ponds & Wells	4.40
Derry	11,700	0.37	Wells	0.60
Franklin	6,750	0.75	Wells	3.00
Goffstown	9,300	1.15	Well & Manchester	N/A[6]
Hooksett	5,640	1.50	Pond & Manchester	N/A[6]
Hudson	10,650	0.50	Wells	1.75
Laconia	15,500	1.30	Paugus Bay	7.63
Londonderry	5,350	0.73	Lake Massabesic	N/A[6]
Manchester	87,750	13.97	Lake Massabesic	22.00
Merrimack	8,600	0.74	Wells	5.18
Milford	6,620	0.64	Wells & Brook	1.92
Nashua	55,820	9.55	Brook & Wells	13.70
Salem	12,000	0.97	Canobie Lake	2.25
TOTALS	271,600	37.38		62.43
GRAND TOTAL	1,153,530	138.77		238.85

[1]Data obtained from local, regional and state planning reports.

[2]In those communities served only by groundwater wells, capacity must be available to meet maximum day demands.

[3]Portion of supplies received from Metropolitan District Commission, Boston (MDC).

[4]Water available as needed by community as part of an agreement with the MDC.

[5]Receives water from Lawrence.

[6]Receives water from Manchester.

8. Chelmsford: Chelmsford is located 24 miles northwest of Boston in the Lowell Metropolitan area. The reported 1970 population of 31,648 represents an increase of 106 percent over its 1960 population. Approximately 100 percent of the population is served through various systems which are 99 percent metered. The water districts have groundwater supplies as their source of water, and the total estimated dependable yield of all sources is 5.80 mgd. Average day demand in 1970 was recorded as 2.36 mgd.

9. Fitchburg: The City of Fitchburg is located about 22 miles north of Worcester in the Basin of the North Nashua River, a tributary of the Merrimack. In 1970, the City recorded a population of 43,343, a figure which reflects the stable population characteristic of this municipality. In 40 years, the City has experienced a population increase of only 3,000. Surface water provides Fitchburg its water supply source. A total of 14 reservoirs, 6 in Fitchburg, 4 in Westminster, 2 in Ashby, and 2 in Hubbardston, have been developed over the years. The estimated safe yield of the system is 11.9 mgd. In 1970, average daily demand was 7.9 mgd, of which about 65% was used for industrial supply. The distribution system serves approximately 90 percent of the population and is 100 percent metered. Treatment consists of disinfection by chlorine, and fluoridation is also practiced.

10. Framingham: Framingham is located about 21 miles west of Boston in the Basin of the Sudbury River, a tributary of the Merrimack. In 1970, Framingham had a population of 63,233, an increase of 45 percent from its 1960 census figure. A municipal water system is operated by the public works department and an estimated 90 percent of the Town's population is serviced by a system which is approximately 90 percent metered. Water supply is drawn from two sources. About 75 percent of the supply is purchased from the MDC's surface water reservoirs, while the remainder is drawn from ground water wells located within the Town. No treatment is provided other than chlorination of the MDC supply. A total of 7.15 mgd was supplied in 1970.

11. Haverhill: The City of Haverhill lies 33 miles north of Boston on the Merrimack River and had a 1970 population of 45,643, a decrease of 1.5 percent from the 1960 census figure. Water supply is delivered by the Public Works Department, and it is estimated that 98 percent of the population is served by the system, which is 92 percent metered. Until 1966, the City sold Groveland, an adjoining town, its water supplies, but Groveland has now developed its

own groundwater supply. Haverhill has three major sources of water supply. The sources include Kenoza Lake, which is fed by Millvale Reservoir with a combined usable storage of 1 billion gallons and 8 square miles of watershed; Crystal Lake which has a usable capacity of 500 mg and a 3 square mile watershed; Johnson's Pond which is located in Groveland and fed from Chadwich's Pond, with a usable capacity of 900 mg and has a watershed of 4.1 square miles. Treatment of the water supply consists of chlorination with the addition of phosphates for corrosion control. Copper sulphate is added at the lakes for control of algae. The estimated safe yield of Haverhill's sources is 8.7 mgd; and in 1970, the average annual demand was 7.0 mgd.

12. <u>Lawrence:</u> The City of Lawrence is located on the Merrimack River about 26 miles north of Boston and had a 1970 population of 66,216, a decrease of 7 percent from the 1960 census figure. Water supply for the City is furnished by a municipal water department, and all residents are provided with 100% metered city water. In addition, the Town of Methuen, with a 1970 population of 34,986, an increase of 24 percent from the 1960 census figure, is supplied water by Lawrence under a contract agreement which expires in 1980. Certain properties within the mill section of the City are supplied through the so-called "Community System" which is, in turn, supplied by the City System. In the event of a fire or a pressure drop to some predetermined low lever, fire pumps located in the various mills would automatically start and force raw water from the Merrimack River into the "Community System" and close the check valves between the Community mains and the Lawrence System. Some industries within the City also have private process or industrial water supplies which utilize the river as a source of supply. The existing treatment facilities have a maximum capacity of 14.5 mgd. Raw water is drawn from the Merrimack River and treated by screening, flocculation, clarification, filtration, absorption, and disinfection. In 1970, water was drawn from the plant at an average annual rate of 9.8 mgd. However, during hot, dry periods, the plant has been taxed to its maximum capacity for short periods of time.

13. <u>Leominster:</u> Leominster is located about 18 miles north of Worcester in central Massachusetts. In 1970, the population of the City was 32,939, an increase of 18 percent over the 1960 recorded figure. The supply sources for Leominster consist of both surface and ground water developments. No-Town, Fall Brook and distribution reservoirs have a total safe yield of 5.75 mgd, while the Wass Meadow and Southeast Corner Wells provide 1.50 mgd. An additional

source of supply is the Wachusett Reservoir, a storage facility of the MDC. Approximately 90 percent of the population is serviced by this system which is 99 percent metered. In 1970, the City supplied 8.07 mgd to its customers with a large proportion of this total supplied to industrial users. In February 1964, the MDC authorized the City of Leominster to withdraw up to 5 mgd from Wachusett Reservoir. At such time as the MDC completes the facilities required to withdraw flow from the Millers River Basin to Quabbin Reservoir, the City will then be authorized to draw up to 10 mgd. Available supplies to the City now total 12.2 mgd; and following completion of the Millers diversion, this total would increase to 17.2 mgd.

14. Lowell: The City of Lowell is located on the Merrimack River about 25 miles northwest of Boston. In 1970, the population of the city was recorded as 92,929, an increase of 1 percent over its 1960 census figure. The Lowell water supply system is operated by a municipal department which services the water needs of 100 percent of the city's population through a distribution system which is 100 percent metered. Historically, the original water system for Lowell was constructed in 1869. Following a typhoid fever epidemic in 1891, the city placed two well fields in operation and abandoned the untreated surface supply. In 1956, increasing demands and declining well water quality forced the City to return to the Merrimack River as its supply source. The existing water treatment plant was placed in operation in 1963 with a design capacity of 10.5 mgd. Unit processes within the plant include chlorination, flocculation, sedimentation and rapid sand filtration. In 1970, water was delivered from the plant at an average annual rate of 10.0 mgd. Finished water delivered by the plant has been plagued by taste and odor problems particularly during low flow periods in the Merrimack River. In addition, during the summer months, output from the plant has been in excess of 14.5 mgd.

15. Natick: Natick is a community located about 17 miles west of Boston, which lies partially in the Basin of the Sudbury River, a tributary of the Merrimack. In 1970, Natick recorded a population of 31,055, an increase of 8 percent since 1960. The municipality draws its entire supply from ground water sources which have a reported* safe yield of 10.20 mgd. The system, which is 100 percent metered, services approximately 100 percent of the population. The average daily demand was 6.50 mgd in 1970.

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*Alternative Regional Water Supply Systems for the Boston Metropolitan Area, prepared for the Metropolitan Area Planning Council, February 1971, by Camp, Dresser & McKee, Inc.

NEW HAMPSHIRE

16. Concord: The City of Concord is the capital of the State of New Hampshire and is located along the mainstem Merrimack River. In 1970, the City recorded a population of 30,022, an increase of 4 percent over the 1960 census figure. Water supply for Concord is drawn from both surface and ground sources. Penacook Lake, located within City boundaries, has been the principal source of supply since 1872. This lake, with an estimated safe yield of 2.9 mgd, provides Concord with approximately 70% of its water, while the remaining 30% is obtained from 4 gravel packed wells at the Pembroke well field. In 1970, these sources combined provided a total of 4.10 mgd, while the estimated safe yield of the system is calculated to be 4.5 mgd.* The system, which is 97 percent metered, serves approximately 95 percent of the city's population. In 1972, a water treatment plant with a capacity of 14 mgd was constructed.

17. Manchester: The City of Manchester is located about 15 miles southeasterly of Concord and is the largest city in New Hampshire. The city lies astride the Merrimack River about 22 miles north of the New Hampshire - Massachusetts state line. In 1970, Manchester's population was recorded as 87,754, a decrease of 1 percent from the 1960 census figure. In 1874, the city's municipal water system was placed in operation. Water was pumped from Lake Massabesic into the new distribution system which included 23 miles of wrought iron pipe and a new distribution reservoir. Over the years, numerous additions and improvements to the distribution system and pumping stations have been made. However, Lake Massabesic is still utilized as the source of supply for the system. The system serves 100 percent of the Manchester population through a system which is 100 percent metered. In 1970, Manchester and five adjoining towns, Auburn, Bedford, Hooksett, Goffstown and Londonderry, were delivered an average supply of 14 mgd. In 1974, a water treatment plant with a capacity of 30 mgd with a potential for expansion to 40 mgd was completed and placed in service. The total estimated safe yield of the Lake with existing facilities and intake elevations is calculated to be 22 mgd.

18. Nashua: Nashua is located about 4 miles north of the Massachusetts - New Hampshire state line. The city lies along the Merrimack River; and in 1970, its population was 55,820, an increase of

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*Based on figures contained in Report on Additional Water Supply for the City of Concord, New Hampshire, April 1965, prepared by Camp, Dresser & McKee, Inc.

43 percent from the 1960 census. Since 1852, Nashua has been supplied with water by the Pennichuck Water Works, an investor-owned company which, by franchise, continues to serve Nashua and some area industries. The system's sources of supply include both ground and surface water sources. Three gravel packed wells located in Nashua have a reported safe yield of 2.5 mgd, while a series of impoundments on Pennichuck Brook have an estimated safe yield of 5.7 mgd. At times, the supply of Pennichuck Brook has been supplemented by pumping from the Souhegan River. The pumping station is presently capable of delivering 5.5 mgd to Pennichuck Brook. The water works supplies approximately 99 percent of the domestic demand of the city and approximately 3.7 mgd to area industries (through a system which is 95 percent metered). In 1970, the total average daily demand on the Pennichuck Water Works was 9.55 mgd.

STATUS OF EXISTING WATER SUPPLY PLANS AND IMPROVEMENTS

19. During and following the drought, a number of communities and regional planning agencies conducted engineering studies to determine methods for augmenting their existing supplies. The following are precis of the reports completed for the communities detailed above:

MASSACHUSETTS

20. Billerica: A report* dated May 1972 recommended expansion of the existing 7 mgd water treatment plant to 14 mgd, and removal of the sewage treatment plant effluent from the Concord River, which is the source of water supply to the Merrimack River. Also recommended were investigations of boundary surveys and sub-surface investigations for an off-stream reservoir site. The estimated construction cost of the water treatment plant expansion is calculated to

*Billerica, Massachusetts -- Report on Water Works Improvements, May 1972, Camp, Dresser & McKee, Inc.

be $4.15 million. The cost estimate of the reservoir, off-stream pumping station and pipeline is calculated to be $2.4 million, not including land costs. It is stated that development of this reservoir would allow adequate supply through the year 2020. At present, the expansion of the treatment plant is under way. Work on the reservoir and appurtenant facilities, however, has not been initiated.

21. Chelmsford: Although the information is not available from previous reports, it would appear that Chelmsford would not be able to meet its maximum daily demand at the present time, unless more groundwater sources have been added. In any event, it is doubtful that Chelmsford will be able to meet its estimated 1990 maximum day demand.

22. Fitchburg: A report* dated 27 August 1973 to the Montachusett Regional Planning Commission indicates that Fitchburg will be able to meet its anticipated short and long term water supply needs because of a significant decrease in industrial water usage and the addition of the proposed Shattuck Reservoir. The reported construction cost of this reservoir with a safe yield of 1.4 mgd is $2.0 million.

23. Framingham: Under the provisions of Framingham's contract with the MDC, the community is allowed to draw a maximum of 22 mgd. The availability of MDC water together with existing ground water supply will allow the town to meet its future supply needs through the year 2020. As in the case of Leominster and Natick, described later, the future water supply outlook for Framingham rests with the MDC system. At present, the MDC system itself requires additional supply; and therefore, the future outlook for these towns will depend on MDC action. Two recently completed Corps of Engineers reports recommended the construction of the Northfield Mountain and Millers River Basin Water Supply Projects. If constructed, these projects would augment the MDC's Quabbin Reservoir and allow the system to meet the needs of serviced communities through 1990.

24. Haverhill: A recently completed report** prepared for the City has evaluated the city's existing supply sources ability to meet future needs. According to this report, immediate improvements and

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*Curran Associates, Inc., Water Supply and Wastewater, The Regional Plan, prepared for the Montachusett Regional Planning Commission, August 1973.

**Haverhill, Massachusetts, Report on Improvements to the Haverhill Water System, October 1971, Prepared by Camp, Dresser & McKee, Inc.

additions to the existing supplies are necessary. Both groundwater and surface water sources were investigated for their potential, and the report concluded that it is unlikely that groundwater sources in sufficient quantity and quality are available for the city's use. The improvement plan recommended in the report is divided into three stages designed to provide Haverhill adequate supply through the year 2025. The first stage would include construction of a 12.0 mgd water treatment plant; and a new intake at Kenoza Lake, an existing supply source. Relocation of the water intake would allow an additional 0.3 mgd in available supply raising the total safe yield to 9.0 mgd. Other items included in the stage one improvements are chlorination facilities at Crystal Lake and pumping station improvements at Johnson's Pond and Millvale Reservoir. The estimated construction cost for stage one work is about 7.5 million dollars. Under the second stage of construction, which would be completed in 1984, the treatment plant at Kenoza would be expanded to 20 mgd; an additional supply source would be developed on Little River via diversions to Kenoza Lake (estimated yield = 2.5 mgd); and new transmission lines from Crystal Lake and Johnson's Pond to Kenoza Lake would be constructed. Total construction costs for stage two are estimated to be about 9.2 million dollars. Stage three improvements are scheduled for the year 2008 and include expansion of the Kenoza Lake treatment plant capacity to 24 mgd; an intake and pumping station on the Merrimack River to deliver an additional 3 mgd through a new transmission main to Kenoza Lake. Total construction costs for stage three are estimated to be 3.3 million dollars.

25. Lawrence: Because of increasing demands, and the fact that the water treatment plant was near its capacity, the city retained a consultant engineer* to investigate the improvements and expansion of the City of Lawrence Water Treatment Plant to meet present and future water needs. As a result of the consultant's studies, they concluded that the existing water treatment plant has sufficient capacity to meet the water needs of Lawrence through 1995, but not of Lawrence and Methuen beyond 1975. However, the existing plant has many deficiencies related to the age of the equipment and the need for abatement of pollution in the Merrimack River by sludge and spent washwater. They felt that the interests of the citizens of Lawrence and Methuen would be best served by a 60 percent expansion of the existing water treatment plant. This expansion would

*Report to City of Lawrence, Massachusetts, on Improvements and Expansion of the Water Treatment Plant, 15 July 1971, prepared by Metcalf & Eddy, Inc.

meet both municipalities' water needs through 1995 and would have an estimated capital cost of $6,400,000.

26. Leominster: A report* recently prepared for the local regional planning agency evaluated the future water supply demands which may be placed on Leominster's system. On the basis of this analysis, the report concludes that existing supplies, together with the additional 5 mgd which may be made available from the MDC, will allow the City to meet its 2020 needs.**

27. Lowell: In response to the difficulties of taste and odor presently being experienced by Lowell with their existing supply system, the city retained a consultant engineer*** to investigate the feasibility and cost of necessary treatment and plant expansion. In their evaluation of the treatment plant capacity necessary at Lowell, the consultants included an analysis for the future water needs of neighboring communities. These communities, Billerica, Chelmsford, Dracut, Tewksbury and Tyngsboro, have been experiencing a more rapid growth than Lowell, and the consultant felt that it may become necessary for them to draw water from the Lowell system. On the basis of their investigations, the city's consultants recommended that the filtration capacity of the existing treatment plant be immediately increased from its 10.5 mgd to a design capacity of 30 mgd. It was reported that this design capacity would allow the City of Lowell to meet its individual maximum daily demands through the year 2015. If all neighboring municipalities joined the system to meet their needs, then the plant would be adequate until 1980. However, the report noted that all neighboring communities would probably not desire to join at once. As a means of eliminating taste and odor problems, the report recommends the use of granular activated carbon filters. Total costs for the treatment plant and appurtenant facilities are estimated to be about $7,000,000.

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*Regional Plan for Water Supply and Wastewater, Montachusett Region, July 1973, prepared by Curran Associates, Inc.

**If the additional 5 mgd by way of the Millers proposal is not made available, existing supplies would suffice through 2005.

***City of Lowell, Massachusetts, Report on Improvements to Water Filtration Plant, September 1972, prepared by Camp, Dresser & McKee, Inc.

28. Natick: In addition to the existing supply sources, another potential source of groundwater with a safe yield of 1.73 mgd has been located and is expected to be developed shortly. The development of this supply would enable the town to meet its supply needs to about the mid 1970's. Beyond that date, new increments of supply would be necessary. As part of the overall NEWS Study effort, two earlier reports* by the Corps of Engineers have been submitted through channels which would supplement the existing supplies of the MDC. In turn, this supplemented MDC supply could be used to provide Natick its future supply needs.

NEW HAMPSHIRE

29. Concord: During the sixties drought, the City of Concord retained an engineering firm** to conduct a comprehensive study of the present sources of water and their adequacy and determine the most feasible additional water supply for future needs. On the basis of their investigations, the firm recommended that the Turkey River be developed as a supplemental source of supply. In addition, the report stated that construction of a water treatment plant at Penacook Lake was necessary to assure excellent quality water. The water treatment plant portion of the proposal with a capacity of 14 mgd has recently been constructed. In a more recent report*** published by the State of New Hampshire, the recommended plan for Concord and 15 surrounding communities in a regional system would be withdrawals of water from the Contoocook River to Penacook Lake. At Penacook Lake, the water would be treated in a water treatment plant and distributed to meet community requirements. In a third

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*The Millers River Basin and Northfield Mountain Water Supply Projects, prepared by the New England Division, to be published in 1975.

**Report on Additional Water Supply for the City of Concord, New Hampshire, Concord Water Works, Concord, New Hampshire, April 1965, Camp, Dresser & McKee, Inc.

***Merrimack River Basin Water Quality Management Plan, prepared by the New Hampshire Water Supply and Pollution Control Commission, Staff Report No. 61, November 1973.

report* on water supply, two further alternatives to furnish water to the Concord region, together with other sections of New Hampshire within the Merrimack River Basin, were investigated. In these plans, the Concord region would draw their future water supply from the mainstem of the Merrimack River. Low flow augmentation storage for these plans would be provided in either the existing Blackwater Reservoir or in a new off-stream reservoir (Maple Falls). The plans included in each of the three engineering plans previously described would, if implemented, provide adequate water supply through 2020. At present, the use of the Contoocook River to supply future needs of Concord and its environs appears to be the plan most favored.

30. Manchester: During the 1960's, prior to and during the drought, a series** of reports on methods to improve or supplement the existing Manchester water supply system were made. In these reports, additional resources which were identified to meet future needs included Black Brook and the north branch of the Lamprey River, both within the Merrimack River Basin. In developing these resources, reservoirs would be constructed and water withdrawn to Lake Massabesic for treatment and delivery to consumers. In addition, one of the reports considered the use of Merrimack River water in conjunction with Black Brook reservoir and described the Merrimack as a potential long range source. In two more recent reports*** dealing with meeting future water needs for Manchester and a number

*Public Water Supply Study -- Phase Two Report, prepared for New Hampshire Office of State Planning, March 1972, by Anderson-Nichols & Company, Inc.

**Report on Additional Water Supply for the Manchester Water Works, Manchester, New Hampshire, November 1960, prepared by Edward S. Brown, Engineer, Hanover, New Hampshire.

Interim Report Improvements to Water System, City of Manchester, New Hampshire, October 1964, prepared by Whitman & Howard Engineers, Inc., Boston, Massachusetts.

Report on Water Supply from Black Brook, Manchester Water Works, Manchester, New Hampshire, August 1967, prepared by Whitman & Howard Engineers, Inc., Boston, Massachusetts.

***op cit (New Hampshire Water Supply & Pollution Control Report #61).

Water Supply and Water Pollution Abatement in the Metropolitan Manchester Regional Area, Southern New Hampshire Planning Commission, September 1970.

of surrounding communities, development* of the mainstem Merrimack is recommended. As proposed in these reports, an intake structure and pumping station located in the vicinity of Martin's Ferry would be constructed on the banks of the Merrimack River. Water withdrawn from the river would be transferred to a water treatment plant at Lake Massabesic and delivered to users after treatment. A third report ** on meeting water supply needs in the Manchester region presents two alternatives. In this study, both plans would supply the Manchester region by drawing from the Merrimack River. In one plan, low flow augmentation storage would be provided by raising the existing Corps of Engineers Blackwater reservoir. The second plan would require construction of an offstream storage reservoir to provide flow augmentation to the region's system during low flow periods on the Merrimack. In both plans, water would be withdrawn from the Merrimack River on a continuous basis, treated and delivered to Manchester and the surrounding communities of Auburn, Bedford, Goffstown, Hooksett and Londonderry. In 1974, Manchester completed construction of a 30 mgd water treatment plant on the shores of Lake Massabesic. Initially, the plant will treat water from the lake, but it is expected that ultimately water from the Merrimack River itself will be used.

31. Nashua: A report*** prepared for the New Hampshire Office of State Planning in 1972 presents two alternatives to meet the water supply needs of the Nashua region. Both plans would draw water from the Merrimack River. One plan would provide storage for water supply by raising the existing Corps of Engineers Blackwater Reservoir. Water would then be drawn from storage, treated and delivered to the Concord, Manchester, and Nashua regions. The second plan would require construction of an offstream storage reservoir to provide flow augmentation to the region's system during low flow periods. Water would then be withdrawn from the Merrimack near Nashua on a continuous basis, treated and delivered to Nashua.

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*The Merrimack would be used following implementation of a diversion during spring flows from Manter Brook which is expected to be an early action plan for Manchester alone. The Manter Brook plan would add 3 mgd to the existing yield.

**Ibid (Anderson-Nichols Report).

***Public Water Supply Study, Phase Two Report, New Hampshire Office of State Planning, March 1972.

and surrounding municipalities. Another report* concerned with meeting the needs of the Nashua area indicated a water treatment plant would be constructed on a site proximate to either Pennichuck Brook or the Souhegan River. A diversion structure and pumping station would be constructed on the Merrimack River in the Town of Merrimack. Diverted water would be pumped directly to the treatment plant. By the year 2020, it will be necessary to withdraw water from the river on a continual basis, except during periods of extreme low flow. During these periods, the water supply would be dependent on offstream storage. As presently envisioned, the system will serve the following seventeen communities: Amherst, Brookline, Derry, Hollis, Hudson, Litchfield, Londonderry, Lyndeboro, Mason, Merrimack, Milford, Mt. Vernon, Nashua, Pelham, Salem, Wilton and Windham. The Nashua Regional Planning Commission completed a Comprehensive Regional Water Quality Management Plan** in December 1973. The consultant recommended a regional water treatment plant on the Merrimack River at Merrimack, New Hampshire, and a second treatment plant near a proposed Soil Conservation Service dam on Purgatory Brook.

FUTURE WATER SUPPLY NEEDS WITHIN THE MERRIMACK RIVER BASIN

32. As described in Section B, communities within both the Massachusetts and New Hampshire portion of the basin are expected to grow and prosper. Associated water requirements for both domestic and industrial usage, based on population and economic forecasts, are also expected to increase sharply. Table C-2 presents information on future water supply needs within communities with existing public supplies. As shown in the Table, water supply needs within the Massachusetts portion of the basin are expected to increase from about 101 mgd in 1970 to almost 170 mgd in 1990 and 249 mgd by 2020.

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*Merrimack River Basin Plan, New Hampshire Water Supply and Pollution Control Commission, February 1972.

**Comprehensive Regional Water Quality Management Plan, Nashua Regional Planning Commission, Howard, Needles, Tammen & Bergendoff, 25 December 1973.

Table C-2. Future Municipal Water Supply Requirements in the Merrimack River Basin

Municipal System	1970 Average Demand	1970 Present[1] Dependable Yield	1990 Population	1990 Average Demand	2020 Population	2020 Average Demand
Massachusetts						
Acton	1.08	2.75	26,500	2.80	43,000	5.53
Amesbury	0.97	3.00	17,000	1.79	19,500	2.63
Andover	3.20	14.50	38,000	7.10	39,000	10.90
Ashland	1.33	4.36	14,400	2.69	22,200	5.08
Ayer	0.85	1.50	8,800	1.24	11,100	1.84
Bedford	1.58	3.30	18,500	3.03	17,800	3.41
Billerica	2.65	14.00	48,900	5.60	48,900	7.30
Chelmsford	2.36	5.80	43,600	5.56	43,600	7.06
Clinton[2]	0.86	N/A[3]	13,000	3.23	15,100	4.14
Concord	1.78	5.50	24,200	3.36	39,400	6.36
Dracut	1.06	2.70	34,000	2.79	37,200	3.90
Fitchburg	7.90	11.90	40,300	10.83	43,600	14.46
Framingham[2]	7.15	2.13	77,500	10.83	91,800	15.26
Gardner	1.63	1.78	18,873	2.10	21,244	2.96
Georgetown	0.41	1.40	7,000	0.80	12,000	1.60
Groton	0.82	1.51	6,700	1.39	11,700	2.95
Groveland	0.55	1.30	11,000	1.37	13,200	1.98
Haverhill	6.20	8.75	55,000	9.70	61,100	12.60
Holden	1.26	1.02	18,100	2.23	24,600	3.58
Hopkinton	0.45	1.30	10,400	1.02	24,400	2.93
Hudson	1.35	2.52	23,600	3.56	30,300	5.66
Lancaster	0.49	1.00	7,200	0.74	11,900	1.49
Lawrence	10.00	14.00	69,000	9.04	71,000	11.51
Leominster[2]	8.07	7.25	44,700	12.04	52,700	16.56
Littleton	0.66	1.80	11,100	1.82	20,300	3.75
Lowell	10.00	10.50	101,200	13.09	100,800	16.42

Table C-2 (Cont'd) Future Municipal Water Supply Requirements in the Merrimack River Basin

Municipal System	1970 Average Demand	1970 Present[1] Dependable Yield	1990 Population	1990 Average Demand	2020 Population	2020 Average Demand
Massachusetts (cont'd)						
Lunenburg	0.28	0.75	10,100	0.61	19,500	1.60
Marlborough[2]	2.41	5.58	35,300	3.57	43,600	5.51
Maynard	0.75	1.04	11,400	2.30	12,900	3.20
Methuen	2.80	N/A[4]	47,000	4.93	48,200	6.23
Natick	6.50	10.16	39,600	7.58	46,300	10.33
Newburyport	2.15	3.35	18,500	3.25	25,000	5.27
North Andover	1.88	3.00	26,000	3.70	29,400	5.30
Northborough[2]	0.70	0.95	14,000	1.75	19,900	2.94
Pepperell	0.54	1.70	15,200	2.17	27,300	4.52
Shrewsbury	1.60	2.90	24,600	2.69	31,900	4.29
Southborough[2]	0.44	N/A[3]	9,400	0.88	17,400	2.05
Sudbury	1.12	3.70	28,500	3.19	45,400	6.08
Tewksbury	1.87	3.30	39,600	4.14	39,600	5.14
Wayland	1.58	5.58	23,300	3.22	36,700	5.87
Westborough	1.01	1.99	21,900	2.31	28,500	3.70
West Boylston	0.48	2.05	8,700	0.85	11,800	1.42
Westford	0.62	4.80	34,100	2.96	35,800	3.96
TOTALS	101.39	176.42	1,195,773	169.85	1,446,644	249.27

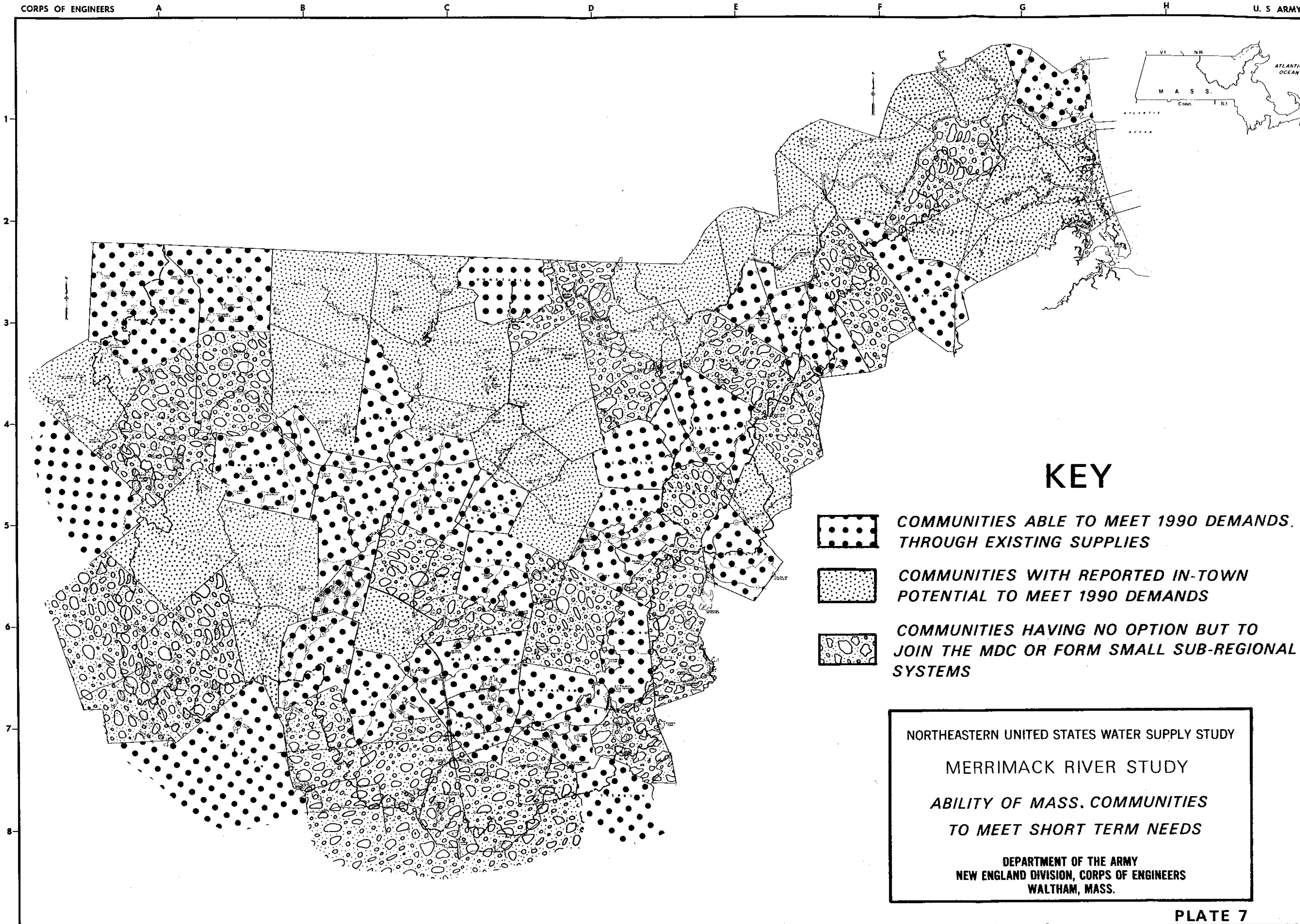
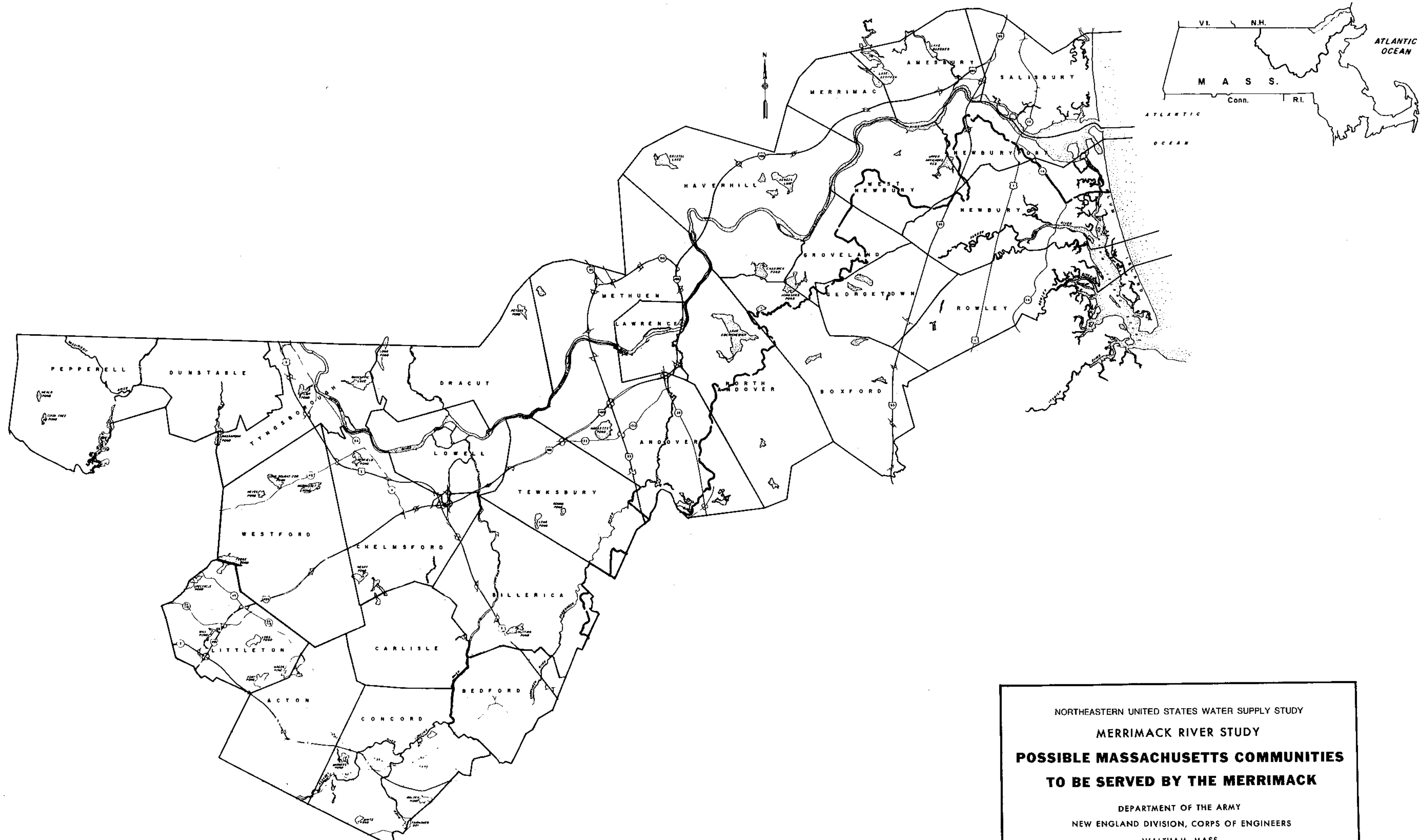

CORPS OF ENGINEERS
U. S ARMY
ATLANTIC OCEAN
KEY
COMMUNITIES ABLE TO MEET 1990 DEMANDS, THROUGH EXISTING SUPPLIES
COMMUNITIES WITH REPORTED IN-TOWN POTENTIAL TO MEET 1990 DEMANDS
COMMUNITIES HAVING NO OPTION BUT TO JOIN THE MDC OR FORM SMALL SUB-REGIONAL SYSTEMS
NORTHEASTERN UNITED STATES WATER SUPPLY STUDY
MERRIMACK RIVER STUDY
ABILITY OF MASS. COMMUNITIES TO MEET SHORT TERM NEEDS
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 7



NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

MERRIMACK RIVER STUDY

POSSIBLE MASSACHUSETTS COMMUNITIES TO BE SERVED BY THE MERRIMACK

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 8

Table C-2 (Cont'd) Future Municipal Water Supply Requirements in the Merrimack River Basin

Municipal System	1970 Average Demand	1970 Present[1] Dependable Yield	1990 Population	1990 Average Demand	2020 Population	2020 Average Demand
New Hampshire[6]						
Bedford	1.10	N/A[5]	20,500	3.60	47,500	11.50
Concord	4.10	4.40	43,000	6.70	74,000	13.20
Derry	0.37	0.60	34,000	3.30	56,000	10.20
Franklin	0.75	3.00	8,600	1.20	14,500	2.60
Goffstown	1.15	N/A[5]	27,000	4.60	58,000	12.00
Hooksett	1.50	N/A[5]	19,500	2.70	32,000	6.80
Hudson	0.50	1.75	26,000	2.80	43,000	8.50
Laconia	1.30	7.63	15,000	1.90	15,000	2.80
Londonderry	0.73	N/A[5]	28,000	3.70	90,000	20.00
Manchester	13.97	22.00	80,000	14.50	72,000	16.00
Merrimack	0.74	5.18	25,000	4.00	58,000	12.00
Milford	0.64	1.92	9,000	1.40	14,500	2.80
Nashua	9.55	13.70	56,000	10.00	68,000	13.00
Salem	0.97	2.25	34,000	5.40	36,000	7.80
TOTALS	37.37	62.43	425,600	65.80	678,500	139.20
GRAND TOTALS	138.77	238.85	1,621,373	235.65	2,125,144	388.47

[1]In those communities served only by groundwater wells, capacity must be available to meet maximum day demands.

[2]Portions of supplies received from Metropolitan District Commission, Boston (MDC).

[3]Water available as needed by community as part of an agreement with the MDC.

[4]Receives water from Lawrence.

[5]Receives water from Manchester.

[6]Projections from the 1972 Office of State Planning Report.

Within the New Hampshire portion of the basin, extensive increases in water supply requirements are also anticipated with the 1970 total of 37 mgd expected to rise to 66 mgd in 1990 and 139 mgd by the year 2020.

ABILITY OF PUBLIC WATER SUPPLY SYSTEMS TO MEET FUTURE IN-BASIN NEEDS

33. As described in the previous paragraphs, during and following the drought a number of communities and regional planning agencies within the basin conducted engineering studies to determine methods for augmenting their existing supplies. In many cases, new sources of supply recommended in these reports have been developed by the communities which will allow them to meet their future requirements. Investigations conducted by the NEWS Study, however, indicated that even with the actions taken by local authorities, additional supplies in many cases must be made available to insure future needs are met.

34. In assessing the capability of local water supply systems, a town-by-town survey was made of municipalities within the Massachusetts segment of the basin. A review was made of available reports which had been prepared for the various communities by consultants for the town themselves or for a regional planning agency. In a number of cases, the review of the reports was supplemented by personal contacts with municipal officials. Since the primary intent of the study was to investigate methods of utilizing the Merrimack as a water supply source for eastern Massachusetts, the survey of local supply system capabilities in New Hampshire was not conducted in the same detail as Massachusetts. Within New Hampshire, instead of a town-by-town analysis, a review was made of reports prepared by state and regional planning agencies and certain key municipalities such as Concord, Manchester and Nashua.

35. Two time periods were used in evaluating the ability of the public water supply systems to meet future in basin needs. Short term or early action supply requirements were considered to be those needs anticipated from the present to the year 1990. Long range needs or requirements which do not require immediate implementation of

facilities were considered to be those needs expected to occur in the 1990-2020 time period. The recommendations of this report reflect this phased view of the future water supply outlook. Accordingly, any recommendations concerning construction of facilities are directed toward meeting the short range needs.

MASSACHUSETTS--SHORT TERM IN-BASIN NEEDS

36. As shown on Plate 7, there are a total of 72 municipalities located either wholly or partially within the Massachusetts portion of the Merrimack River Basin. Of this total, 37 communities have existing supplies which will allow them to meet their expected 1990 supply requirements. Another 16 towns have reported in-town potential which, if developed, would allow them to satisfy their 1990 needs. The remaining 19 cities and towns reportedly must either join the existing regional Metropolitan District Commission system or join with other communities in sharing a common supply source. As shown on Plate 7, the communities located in the western half of the basin can generally meet their 1990 needs through either existing or in-town sources. These western basin municipalities are generally smaller rural type towns which are expected to develop relatively small ground or surface water sources to meet their needs. In the southwestern segment of the basin, a number of communities are in proximity to either aqueducts or towns presently serviced by the MDC, and it is anticipated that a number of these towns will, in the future, be served by that system.

37. A number of the cities and towns located in the northeast quadrant of the Massachusetts section of the basin will require augmentation of their systems if they are to meet 1990 needs. These communities, many of which lie adjacent to the Merrimack River mainstem, list development of the Merrimack River itself as an alternative to their own local source. These communities, listed in Table C-3 and shown in Plate 8, were considered in this study as possible candidates to be served by a regional system designed to meet short range water supply needs.

NEW HAMPSHIRE--SHORT TERM IN-BASIN NEEDS

38. Within the New Hampshire portion of the basin, a large proportion of the 1990 needs will be met by two recently completed water treatment plants. These plants which provide supply to Concord, Manchester and their environs are sized at 14 and 30 mgd, respectively,

TABLE C-3

Possible Massachusetts Communities to be Served by the Merrimack River

Acton	Littleton
Amesbury	Lowell
Andover	Merrimac
Bedford	Methuen
Billerica	Newbury
Boxford	Newburyport
Carlisle	North Andover
Chelmsford	Pepperell
Concord	Rowley
Dracut	Salisbury
Dunstable	Tewksbury
Georgetown	Tyngsborough
Groveland	Westford
Haverhill	West Newbury
Lawrence	

and are expected to supply those regions' needs at least through 1990. The Nashua region, which is the second largest urban area within the New Hampshire portion of the basin, however, does not at present have existing supplies adequate to meet 1990 requirements. The potential of serving this region's short range needs from a water treatment plant located within Massachusetts, therefore, was considered as part of this study.

MASSACHUSETTS/NEW HAMPSHIRE LONG TERM IN-BASIN NEEDS

39. When the Merrimack Basin's water supply needs are viewed from the longer range (1990-2020) perspective, the inadequacy of locally available resources to meet these needs becomes evident. Within the Massachusetts portion of the basin, a number of communities particularly within the central section will have exhausted their options for local resource development. These communities shown on Plate 9 will be required to join some form of regional system in order to meet their expected water supply needs. Development of the Merrimack River to meet these needs offers a viable means of delivering the necessary supply. Within the New Hampshire river reaches, a similar situation with regard to the ability of local resource potential to meet long range needs also appears to be developing. An illustration of cities and towns which may require supply from a regional system is given on Plate 9. Municipalities in New Hampshire as well as Massachusetts, therefore, can be expected to call upon the Merrimack River itself as a major source of supply.

FUTURE OUT-OF-BASIN WATER SUPPLY SYSTEMS TO MEET FORECAST FUTURE WATER SUPPLY DEMANDS

40. Earlier investigations* conducted as part of the NEWS study within southeastern New England demonstrated that the Merrimack River may have considerable potential for meeting some of the future out of basin needs within the region. The role which the Merrimack may play in satisfying these future demands, particularly in the longer range years from 1990 to 2020, necessitated investigating these water supply forecasts as part of this study. In the following paragraphs, estimates of the various communities' water supply needs together with a description of the various public water supply systems ability to meet these needs is given. An identification is also made of those communities which based on available information will be required to seek water from a regional system.

41. The heart of the eastern Massachusetts Region, which is located outside of the Merrimack River Basin, is Boston and its environs. In terms of population, employment and other economic indicators, for example, this area is the largest in New England. The region is far from homogenous, however, and there are many smaller communities, wide differences in per capita income and many employment centers within the various communities. In general, however, the Boston region is expected to continue to grow in population, employment, and personal income although at a slower rate than some of its surrounding economic regions. Even with this reduced growth rate, the Boston region and its associated water supply requirements can be expected to form the backbone for the development of any region-wide supply system. Information on estimated municipal and industrial water supply needs from public systems in eastern Massachusetts is shown on Table C-4. As given in the table, water supply needs for communities in the various eastern Massachusetts counties located outside of the Merrimack River Basin can be expected to rise from 529 mgd in 1970 to about 758 mgd in 1990, and 1038 mgd by the year 2020.

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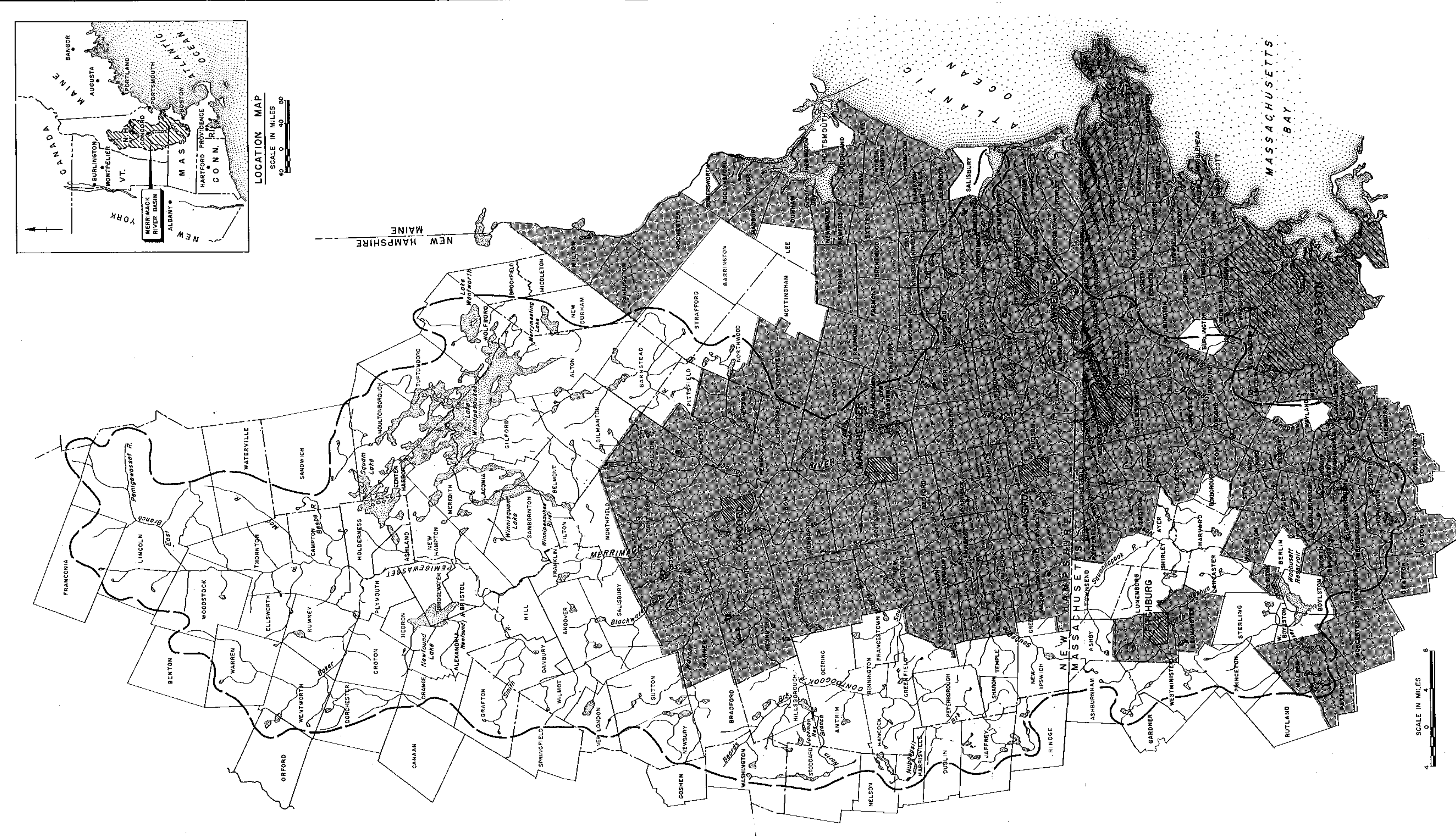
* Draft Feasibility Report on Alternative Regional Water Supply Plans for Southeastern New England prepared by the New England Division Corps of Engineers, November 1969.



NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

MERRIMACK RIVER STUDY

COMMUNITIES WITH LONG RANGE NEEDS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

Table C-4. Future Water Requirements for Out of Basin Communities

County	1970	1990	2020
Essex	49	76	107
Middlesex	136	200	255
Suffolk	151	193	250
Norfolk	56	93	140
Plymouth	32	58	83
Bristol	61	94	133
Worcester	44	44	70
TOTALS	529	758	1038

ABILITY OF OUT-OF-BASIN WATER SUPPLY SYSTEMS TO MEET FORECAST FUTURE NEEDS

MASSACHUSETTS

42. In any evaluation of the out of basin water supply systems ability to meet future water requirements, a number of active proposals to augment existing supplies must be considered. As described earlier, the feasibility report on possible engineering alternatives for meeting future water supply needs of the region was completed in November 1969. Following the receipt of comments on the report, a meeting was held in May 1970 with Federal, State and local organizations, and three project oriented investigations were recommended for further study. Although the objective of the May 1970 meeting was to select high priority items for immediate investigations and not to select a "best" regional plan, the recommended detailed investigations were intended to yield project components for a short term (1990) regional plan. In addition, actions by others interested in the

region's water supply outlook, such as State, Regional and local agencies, have selected other components of the short term plan. The projects recommended to the Corps for detailed investigation at the May 1970 meeting together with actions by others have, therefore, formulated a defacto plan to meet the short term water supply needs of many of the out of basin communities. The projects which make up this defacto plan are described in the following paragraphs and pertinent data are given in Table C-5. An illustration of the projects' locations and service areas is given in Plate 10.

Table C-5. Pertinent Data
1990 "Defacto" Regional Plan

Project	Source	Service Area	Yield mgd	Capital Cost ($1x10^6$$)	Cost per mg ($1/mg)
Northfield Mountain	Connecticut River	Boston Metropolitan	72	50.9	155
Millers River Basin	Connecticut River	Boston Metropolitan	76	53.4	157
Ipswich River	Ipswich River	Boston North Shore	25	32.0	354
South Shore Local Development	South Shore Coastal	Brockton and Vicinity	10		
Weweantic River	Buzzards Bay Coastal	Taunton - New Bedford - Fall River	15		

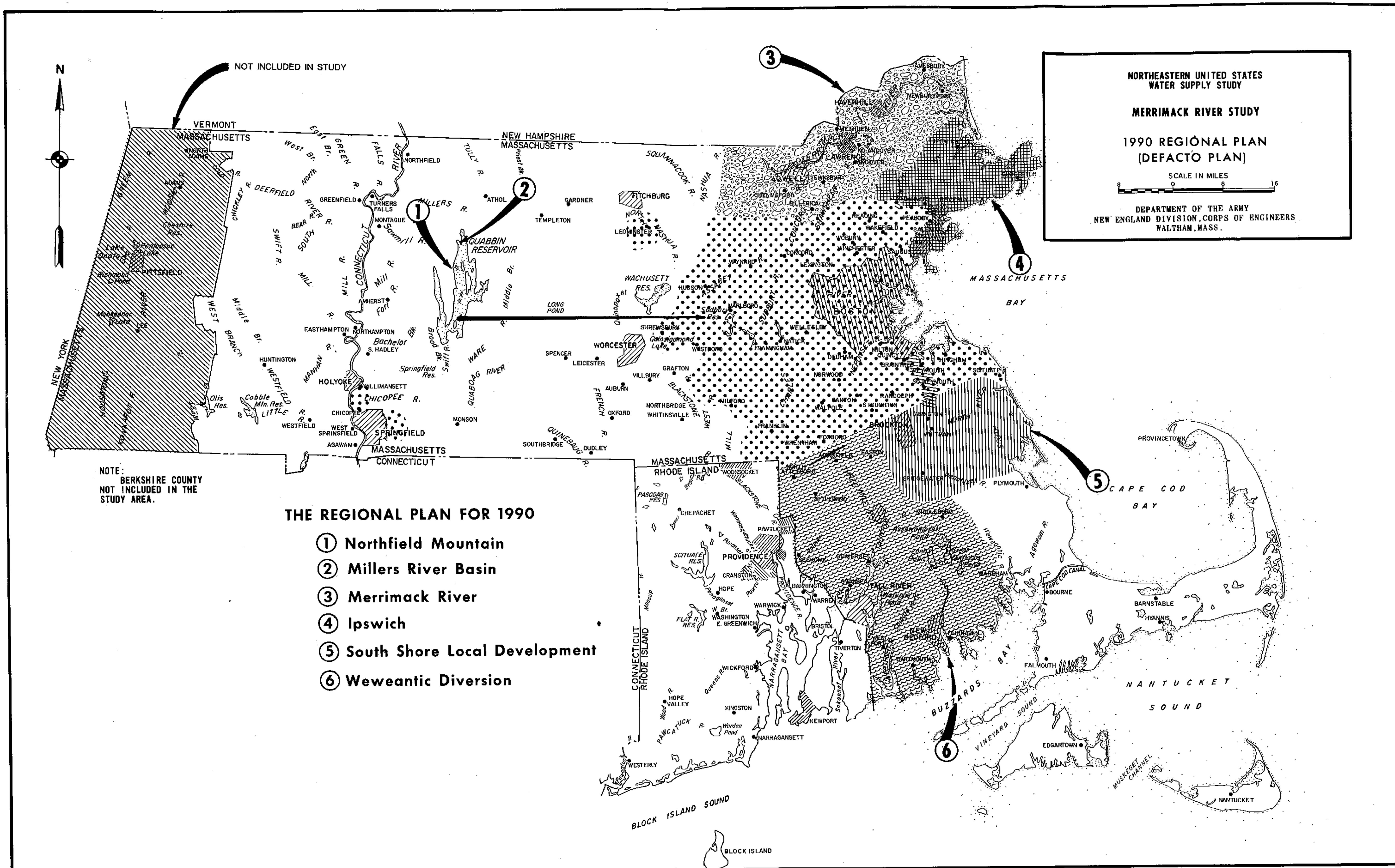

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
MERRIMACK RIVER STUDY
1990 REGIONAL PLAN
(DEFACTO PLAN)
SCALE IN MILES
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.
NOT INCLUDED IN STUDY
NOTE:
BERKSHIRE COUNTY
NOT INCLUDED IN THE
STUDY AREA.
THE REGIONAL PLAN FOR 1990
1 Northfield Mountain
2 Millers River Basin
3 Merrimack River
4 Ipswich
5 South Shore Local Development
6 Weweantic Diversion
VERMONT
MASSACHUSETTS
NEW HAMPSHIRE
MASSACHUSETTS
NEW YORK
MASSACHUSETTS
MASSACHUSETTS
CONNECTICUT
MASSACHUSETTS
RHODE ISLAND
CONNECTICUT
RHODE ISLAND
QUABBIN RESERVOIR
WACHUSETT RES.
MASSACHUSETTS BAY
CAPE COD BAY
BUZZARDS BAY
NANTUCKET SOUND
VINEYARD SOUND
BLOCK ISLAND SOUND
BLOCK ISLAND
PITTSFIELD
GREENFIELD
NORTHFIELD
ATHOL
GARDNER
FITCHBURG
LEOMINSTER
TEMPLETON
WORCESTER
SPRINGFIELD
HOLYOKE
CHICOPEE
WESTFIELD
WEST SPRINGFIELD
AGAWAM
NORTHAMPTON
EASTHAMPTON
AMHERST
HUNTINGTON
MONSON
SPENCER
LEICESTER
AUBURN
OXFORD
SOUTHBRIDGE
DUDLEY
HAVERHILL
LAWRENCE
LOWELL
BOSTON
BROCKTON
PLYMOUTH
PROVIDENCE
PAWTUCKET
CRANSTON
WARWICK
FALL RIVER
NEW BEDFORD
NEWPORT
WESTERLY
KINGSTON
NARRAGANSETT
BOURNE
FALMOUTH
BARNSTABLE
HYANNIS
PROVINCETOWN
EDGARTOWN
NANTUCKET

PLATE 10

43. Two of the projects which are components of the 1990 regional plan have been recommended for construction and are presently under review at the Office, Chief of Engineers. These are the Northfield Mountain and Millers River Basin projects. Interest in early implementation of these projects by the Commonwealth of Massachusetts has continued from the May 1970 meeting to present. In August 1973, the Massachusetts Water Resources Commission stated in correspondence strong support for the planning and implementation of both projects. In March 1975, the Governor of Massachusetts reiterated the Water Resources Commission's earlier position in a letter to the New England Division of the Corps of Engineers. Following review by the Board of Engineers for Rivers and Harbors (BERH) in March 1975, both projects were endorsed and recommended for construction. When implemented, the Northfield Mountain and Millers River Basin projects will augment the existing sources of the Metropolitan District Commission (MDC) and allow those communities presently served by the system and others, whose supplies are limited, to meet their water supply needs to about the year 1990.

44. The third project-oriented item of work, selected at the May 1970 meeting, recommended that the potential use of the Merrimack River as a water supply source be investigated, and as stated earlier, this is the purpose of this report.

45. In addition to the Corps of Engineers water supply planning activities within the region, State, regional planning and local officials are also conducting studies on methods to meet future water needs. The efforts by these other interested officials provide information on other projects which, when implemented, will aid in satisfying other future needs for out of basin municipalities, particularly in the short range (1990). A description of the efforts of these other agencies is given in the following paragraphs.

46. The Commonwealth of Massachusetts has recently prepared a report on development of a water supply storage reservoir within the Ipswich River Basin. This planned reservoir would use flood skimmed flows from the mainstem Ipswich River. Water from the reservoir would be treated and supplied to a number of municipalities located north of Boston. The addition of the Ipswich River reservoir to the region's water supply facilities would allow the communities shown on Plate 10 to meet their future supply demands to about the year 2000.

47. Two regional planning agencies within Massachusetts located to the south of Boston and outside of the Merrimack Basin have also made extensive investigations on means for meeting their area's 1990 supply needs. In the Brockton metropolitan area and surrounding municipalities, development of local ground water supplies and diversion of flow from a number of small coastal streams to the existing Silver Lake System is expected to yield adequate supplies through 1990. In the New Bedford - Fall River - Taunton, Massachusetts metropolitan area, further development of the existing Lakeville Ponds storage complex by diversion of flow from the Weweantic River is recommended as the first step in that region's plan. It is expected that this development together with some other smaller projects would allow that area to meet its anticipated 1990 supply needs. The two regions and the communities which would be served by the proposed developments are shown on Plate No. 10.

48. In summary, it appears that few out of basin communities within Massachusetts will require augmentation of their supplies from the Merrimack River to meet 1990 needs. Those municipalities which do require additional supply are moving toward development of locally available sources which should allow them to meet their short range needs. In the case of the MDC, local supplies are not available but the Commonwealth of Massachusetts has already stated its desire for the Northfield Mountain and Millers River Basin projects to supplement the yield of that system.

49. In the long range view for the region (1990 - 2020), however, the development of the Merrimack River to service out of basin needs is a viable alternative. The determination of which communities might require supply from a large regional system followed the procedures described earlier for the in basin public water supply systems. This procedure includes preparation of future water demand estimates, a review of available community and regional planning agency reports, and a comparison of available and potential resource development to estimated supply requirement.

50. On the basis of these investigations, a number of communities will require water supplied from a regional system during the 1990 - 2020 era. The majority of these municipalities are those presently served by the MDC system and others identified as requiring connection in order to meet 1990 supply needs. In addition, communities in the Ipswich River Basin are expected to require additional supply, although the implementation of the earlier described

reservoir proposal will allow these communities to be independent beyond the year 2000. On the south shore, municipalities in the Brockton metropolitan area will be seeking new sources shortly after 1990. Connections to a regional supply system such as one which could be served with Merrimack River water is cited as a major option. In addition, other communities in southwestern Norfolk and central Worcester Counties are also expected to have exhausted their local resource potential shortly after 1990, and these towns could also be expected to join a regional system. A plan of these communities which will require additional supply beyond their existing and proposed developments is shown on Plate 11.

51. The total 2020 demand for those municipalities described in the preceding paragraph is estimated to be about 974 mgd. Existing and expected potential development within the communities shown is estimated to be about 317 mgd. The existing MDC system has a reported safe yield of 300 mgd, and the proposed Northfield Mountain and Millers River Basin water supply projects would add on additional 148 mgd for a total (local and regional) of 765 mgd. Thus the water supply requirement which could be delivered by a large regional system utilizing the Merrimack River could total about 209 mgd by the year 2020.

NEW HAMPSHIRE

52. Within the State of New Hampshire, long range water supply needs in its coastal area are forecast to outstrip the capability of its locally available resources. In order to meet this region's long range needs, importation of water may be necessary. In several recent reports, the Merrimack River Basin has been discussed as the coastal zone's future water supply source and various alternatives to divert water have been described. The study charge for this NEWS report was to investigate the potential of utilizing the Merrimack as a water supply source for eastern Massachusetts and possibly southeastern New Hampshire. The potential diversion upstream in New Hampshire to the coastal area was, however, considered with regard to its possible impact on any of the alternatives considered for eastern Massachusetts. On the basis of the investigations conducted, it appears that withdrawals from the river could be made without significant impact on downstream developments provided the diversion withdrawals were limited to high flow periods. The state of New Hampshire in their report "Water Quality Management Plan - Merrimack River Basin," November 1973, state that "water diverted from the Merrimack River at periods of peak flow would be pumped out of the watershed to a large reservoir system in south-central New Hampshire." On the basis of this statement, then, it would appear that New Hampshire is planning to use a high flow skimming technique to supply the coastal region.

OTHER WATER RESOURCE NEEDS WITHIN THE MASSACHUSETTS PORTION OF THE BASIN

53. There are many basin problems or needs related to water supply, because they result from the distribution and flow of water, just as does water supply. One of the greatest problems in the Merrimack River Basin is the deterioration of its water quality. Besides the need for a better quality of water in much of the basin, the river is also used for the generation of hydroelectric power, navigation, and, to some degree, for recreation purposes. These allied water resource needs were considered in this report in connection with possible development of the Merrimack River for water supply purposes.

WATER QUALITY

54. Plans* to improve existing water quality in the Massachusetts portion of the mainstem Merrimack River were recently prepared by the Corps of Engineers as part of the Northeastern United States Water Supply Study. The recommended plan to meet the water quality goals of PL 92-500 called for a total of three secondary and six advanced wastewater treatment facilities. All secondary facilities applied conventional treatment technology while advanced treatment systems utilized either water-oriented technology or land-oriented treatment techniques. Land treatment was achieved with either rapid infiltration basins or spray irrigation systems. In the design of the various treatment systems, a 7-day, 10-year return low flow was used to define the receiving water flow in the Merrimack River. This 7-day flow is calculated to be 980 cfs at Lowell, and 1,000 cfs at Lawrence, Massachusetts. Clearly, any water supply proposal which would disrupt the river's flow rates below these design figures would directly affect the planned water quality improvements.

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* Merrimack Wastewater Management, Key to a Clean River, prepared by the New England Division, Corps of Engineers, in cooperation with the North Atlantic Division; the Environmental Protection Agency; and the Commonwealth of Massachusetts, November 1974.

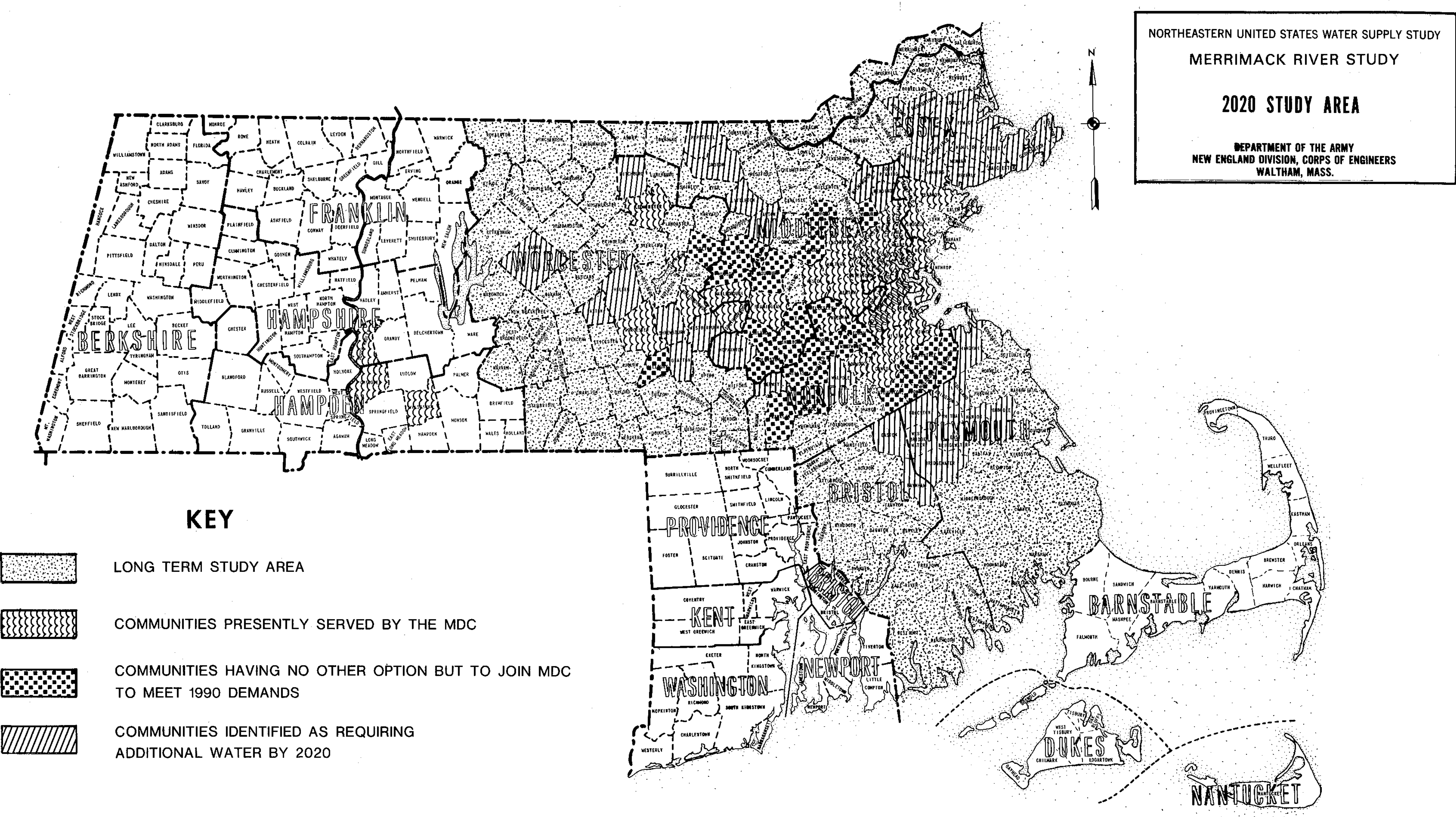
NORTHEASTERN UNITED STATES WATER SUPPLY STUDY
MERRIMACK RIVER STUDY
2020 STUDY AREA
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.
N
KEY
LONG TERM STUDY AREA
COMMUNITIES PRESENTLY SERVED BY THE MDC
COMMUNITIES HAVING NO OTHER OPTION BUT TO JOIN MDC TO MEET 1990 DEMANDS
COMMUNITIES IDENTIFIED AS REQUIRING ADDITIONAL WATER BY 2020
BERKSHIRE
FRANKLIN
HAMPSHIRE
HAMPDEN
WORCESTER
MIDDLESEX
ESSEX
NORFOLK
PLYMOUTH
BRISTOL
PROVIDENCE
KENT
WASHINGTON
NEWPORT
BARNSTABLE
DUKES
NANTUCKET

PLATE 11

HYDROELECTRIC POWER

55. There is a continued growing demand for electric power in the New England area. The recently published 1970 National Power Survey by the Federal Power Commission clearly defines this increasing power demand. The major portion of the power utilized in the Merrimack River Basin comes from power plants located outside of the basin. A network of high voltage transmission lines interconnects the basin with major generating facilities and load centers of the surrounding area. Within the basin, there are a total of 25 hydroelectric projects which have an installed capacity of 70,800 kilowatts which supplies an average of 289 million kilowatt-hours annually. Pertinent data for each of the 25 existing hydroelectric projects are summarized in Table C-6 and shown on Plate 12. Plants located downstream from a water supply intake could, of course, be affected by upstream withdrawals, In this report, the various water supply alternatives were located upstream from Projects 1-7, shown in Table C-6.

56. Project numbers 1 - 5 are supplied water from the Essex Dam in Lawrence, Massachusetts. The dam, privately owned, was completed in 1848 and delivers water through two canals to an industrial complex located between the canals and the Merrimack River. Maximum carrying capacity as reported in a recent report* is about 2951 cfs in the North Canal and 905 cfs in the South Canal. The Fisheries report also stated that no further expansion of hydropower capacity is contemplated at the Essex Complex.

57. Project numbers 6 and 7 draw their water from the Merrimack via a series of canals to an industrial complex in the city of Lowell. The canal system has two intakes from the pool. Maximum carrying capacity of the canal system is estimated** to be about 7,000 cfs supplied through the northern canal and 1,500 cfs in the Pawtucket canal. It has been reported** that no future expansion of hydropower capacity is contemplated at the Pawtucket Dam complex.

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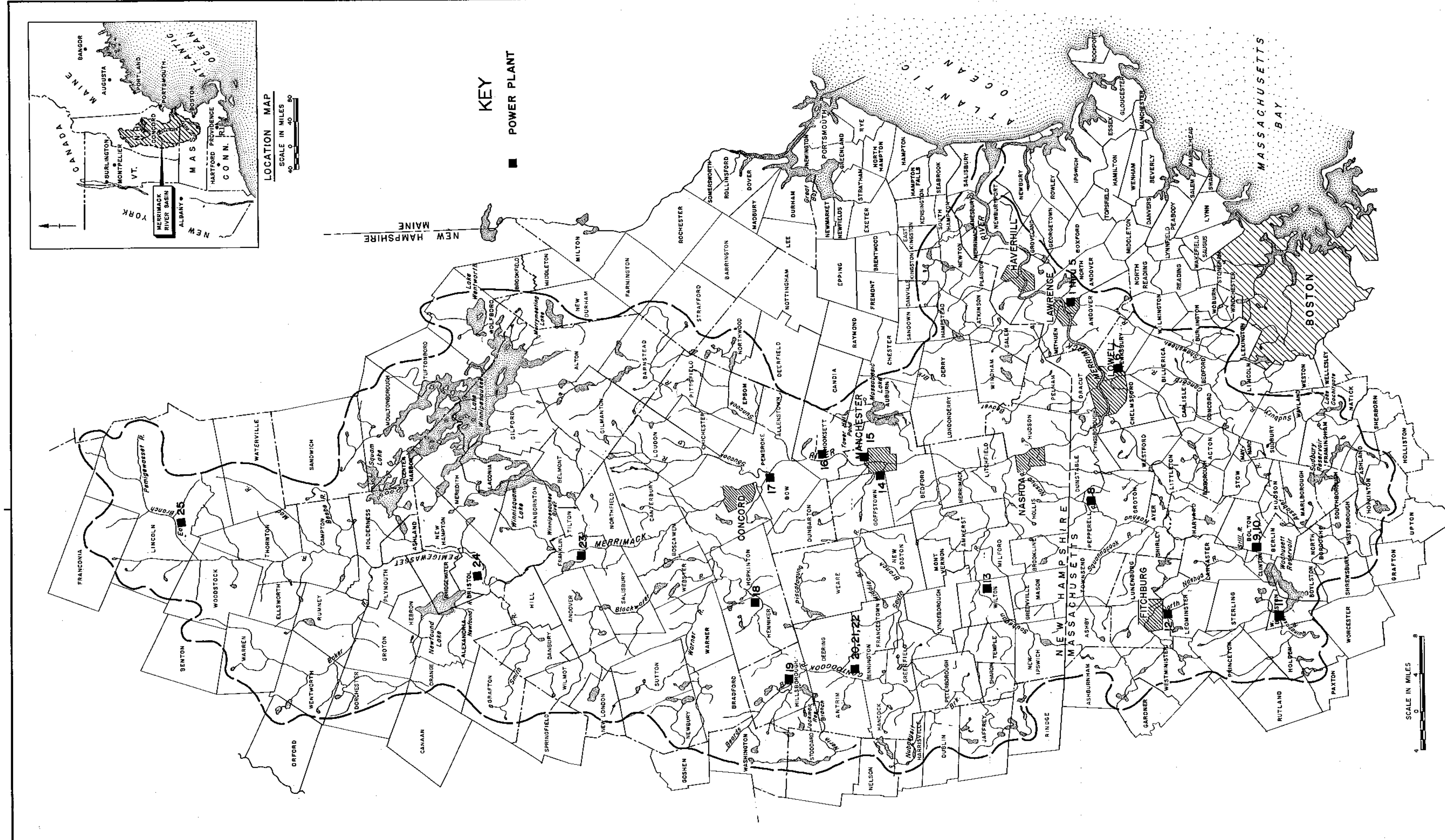
* Fish Passage Facilities, Design Parameters for Merrimack River Basin, Essex Dam, Lawrence, Massachusetts, and Pawtucket Dam, Lowell, Massachusetts. Prepared by the Technical Committee for Fisheries Management of the Merrimack River Basin, January 1975.

** op cit, page

Table C-6. Existing Hydroelectric Projects
Merrimack River Basin

Map No.	Project Name	River	Owner	Licensed Project No.	Drainage Area (sq. mi.)	Gross Head (ft.)	Installed Capacity (kw)	Average Annual Output (1,000 kwh
1	Canal Street[1]	Merrimack	Rowland Industries, Inc.	--	4,461	NA	1,920	6,000
2	Canal Street[1]	Merrimack	Atlantic Enterprises, Inc.	--	4,461	NA	1,400	4,000
3	Canal Street[1]	Merrimack	Aquamac Corp.	--	4,461	NA	900	4,500
4	Merrimack[1]	Merrimack	Merrimack Paper Co.	--	4,461	30	600	2,300
5	Lawrence[1]	Merrimack	Oxford Paper Co., Inc.	--	4,461	26	1,200	6,100
6	Lowell[2]	Merrimack	Boott Mills	--	3,979	40	4,975	8,900
7	Lowell[2]	Merrimack	Boott Mills	--	3,979	40	3,700[3]	12,300
8	Pepperell	Nashua	Pepperell Paper Co.	2623	316	28	1,280	5,600
9	Wachusett	S. Br. Nashua	Metropolitan District Comm.	--	108	98	3,200	8,100
10	Wachusett Intake	S. Br. Nashua	Metropolitan District Comm.	--	108	80	3,200	10,300
11	Oakdale[4]	Stillwater	Metropolitan District Comm.	--	186	135	3,500	10,600
12	Fitchburg	North Nashua	Weyerhaeuser Co.	--	40	98	760	1,200
13	Wilton	Souhegan	Hillsborough Mills	--	97	38	600	1,000
14	Kelleys	Piscataquog	Public Service Co. of N. H.	--	231	21	1,000	2,000
15	Amoskeag	Merrimack	Public Service Co. of N. H.	1893	2,854	45	16,000	82,700
16	Hooksett	Merrimack	Public Service Co. of N. H.	1913	2,805	14	1,600	10,800
17	Garvins	Merrimack	Public Service Co. of N. H.	2140	2,427	30	7,200	40,000



NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

MERRIMACK RIVER STUDY

HYDRO ELECTRIC PROJECTS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

Table C-6 (Cont'd) Existing Hydroelectric Projects
Merrimack River Basin

Map No.	Project Name	River	Owner	Licensed Project No.	Drainage Area (sq. mi.)	Gross Head (ft.)	Installed Capacity (kw)	Average Annual Output (1,000 kwh
18	W. Hopkinton	Contoocook	Hoague Sprague Co.	--	416	20	500	1,300
19	Jackman	N. Br. Contoocook	Public Service Co. of N. H.	--	67	178	3,200	8,000
20	Pierce Station[5]	Contoocook	Monadnock Mills, Inc.	--	192	24	720	1,200
21	Mill Wheel[5]	Contoocook	Monadnock Mills, Inc.	--	192	30	750	1,900
22	Monadnock Mills	Contoocook	Monadnock Mills, Inc.	--	192	NA	125	NA
23	Eastman Falls	Pemigewasset	Public Service Co. of N.H.	2457	1,000	33	3,000	17,200
24	Ayers Island	Pemigewasset	Public Service Co. of N. H.	2456	760	80	8,400	38,000
25	Lincoln	E. Br. Pemigewasset	Franconia Paper Corp.	--	110	50	1,025	4,500
	TOTALS						70,755	288,500

[1] Plants fed by canal from Essex Dam.

[2] Plants fed by canal from Pawtucket Dam.

[3] Total for two plants.

[4] Receives water supply from Quabbin Reservoir aqueduct (Connecticut River Basin) and discharges into Wachusett Reservoir.

[5] Known jointly as Bennington Development.

58. On the basis of presently available information, it appears that the two existing hydroelectric facilities at Lawrence and Lowell, Massachusetts, are in active status. Although not major power generators, the dams do provide a number of manufacturers with their energy requirements and therefore they must be considered in any water supply planning. At present, flow rates of about 3,900 cfs and 3,500 cfs at Lawrence and Lowell, respectively, are reported as satisfactory to meet generating capacity needs.

ANADROMOUS FISH RESTORATION

59. Historically, the Merrimack River provided spawning grounds for several species of anadromous fish. Pollution and the construction of numerous dams have caused the virtual elimination of annual runs of fish in the Merrimack. According to the Technical Committee for Fisheries Management of the Merrimack River Basin, there are seven species of anadromous fish currently under investigation to determine their potential for restoration to the Merrimack River. Each is viewed as potentially restorable for commercial or sport fishing because of the historical presence and/or changes which can be made for successful establishment in the river. Species being considered for restoration are the shad, Atlantic Salmon, alewife, blueback herring, Atlantic sturgeon, striped bass and smelt. Of the potentially restorable species, active programs exist only for the Atlantic Salmon and the shad.

60. Restoration of anadromous fish runs to the Merrimack River could have both a recreational and commercial benefit. From a commercial viewpoint, alewives appear to be the more significant species. Although difficult to estimate, this potential fishery in the past was bountiful and the Merrimack system might easily support a fishery of a million pounds or more. At a commercial value of 15 cents a pound, this could add up to something over $150,000 a year. There are, as yet, no firm estimates of the impact of the salmon and shad portion of the restoration program on the commercial fisheries. The main planning emphasis has been on bringing back the salmon and shad runs in the context of a sports fishery.

61. The current objectives of the restoration program call for establishing an annual run of Atlantic Salmon of approximately 11,000 adult fish from the ocean toward the spawning grounds. For shad, the goal is a run of 1,000,000 spawning age fish. It is expected that anglers will be able to catch from 15 to 25% of the migrating salmon and 20% of the shad.

62. Salmon fishing is, by and large, an upper income sport. It requires large initial expenditures for equipment and the like and a serious fisherman might spend $500 prior to his first day of salmon fishing. In addition, catch ratios for salmon are low; it has been estimated that 20 days of fishing effort are required for each salmon caught. This particular fishery, therefore, requires a special kind of fisherman; one with both the time and money to support the sport. The value of the sport fishery for migrating river salmon is thus difficult to judge and quite dependent upon one's assumptions. Several different estimating techniques have been used and an average value of between $575,000 and $920,000, depending on the catch rates is considered a reasonable economic benefit of the salmon fishery.

63. It is anticipated that the shad fishery, if re-introduction is as successful as expected, will present a far different picture from the salmon fishery. The runs will be large, about 1,000,000 adults in an average year. Catches are estimated at 20% or 200,000 fish. The required fishing effort will be low and is estimated at one fish per recreation day and outlays to enter the fishery are minimal, about $12. In contrast to the salmon fishery, it is expected that shad should attract local residents anxious to combine sport with a chance of augmenting the family diet. The value of a restored shad fishery in the Merrimack River can be estimated by various measures. In view of current developments in costs of food, the value of shad can be expected to increase. Accordingly, a value of the shad fishery of $1,300,000 per year seems to be a reasonable measure.

64. Thus, the total potential value of the salmon and shad fishery on the Merrimack appears to lie in a range between $1,900,000 and $2,200,000 per year. It could be as low as $1,250,000 and as high as $3,000,000, depending upon the assumptions employed regarding the value of the fishing activity and the size of the salmon catch. Most of the benefit from the shad fishery would go to the local economy, while probably about half of the benefits from the salmon fishery would be realized in the immediate region.

65. It has been reported that numerous dams along the Merrimack River and its tributaries are the principal cause for the virtual absence of anadromous species from the Merrimack. Pollution, however, has also been a major factor contributing to the decline of anadromous fish populations. Existing water quality must be at least maintained and, if possible, improved in order for successful restoration of salmon and shad to occur. Diversions of large volumes

of water considered in some of the water supply alternatives could be deleterious to possible future runs of anadromous fish. Large diversions could, for example, alter chemical and physical properties of river water; affect homing, spawning success and juvenile development; delay migration; limit runs; and promote physical barriers to successful restoration.

66. In recognition of the close interplay between development of the Merrimack River for water supply purposes and the goals of the anadromous fish restoration program, this report conducted extensive investigations into the impacts which any of the water supply projects might have on the proposed fishery. In a method designed to minimize any potential impacts, a determination of base flow requirements was made. These base flows would meet the needs of restored anadromous fish during migration, breeding and residence in those river reaches which might be affected by any water supply diversion. Special emphasis was placed on flow rate maintenance for operation of fishways, for habitat support, and for purposes of up and downstream migration. On the basis of these investigations, the flow rates given below were developed. It should be noted that natural flows during late summer and early fall months (July through November) are often below the calculated base flow rates. Additionally, temperature levels during these months are often at or above the 22 - 25° C requirements for shad and Atlantic Salmon. Thus, late summer migrations are not likely in the Merrimack. This, however, was most probably the case, historically as well.

Anadromous Fish Flow Requirements (cfs)
Merrimack River at Lowell

Month	Calculated Flow Rate	Historical Average Flow Rate
January	2,000	5,000
February	2,000	6,200
March	6,000	10,400
April	6,000	17,000
May	4,000	9,600
June	4,000	5,000
July	3,500	3,000
August	3,500	2,400
September	3,500	2,200
October	3,500	3,000
November	3,500	3,000
December	2,000	5,400

SUMMARY

67. In summary, there are many water resource needs currently being satisfied by the Merrimack River Basin. Development of the basin particularly for out of basin diversions must be evaluated in consonance with these other resource needs. As shown in Table C-7, the lowest flow constraint on potential development is related to meeting improved water quality. The highest flow values are required for existing hydroelectric development and for the proposed anadromous fish restoration program. The adoption of any of these flow rates as a control on the water supply project operation will, of course, strongly influence the economics of the water supply development. In Section G, the implications of these flow rates and their impact on construction and operation costs as well as available water supply yield are described and discussed.

Table C-7. Allied Water Resource Flow Needs* (cfs)
Merrimack River at Lowell, Massachusetts

Month	Water Quality	Existing Hydroelectric Power	Anadromous Fish Restoration Program	Average Monthly Flow
January	980	3,500	2,000	5,000
February	980	3,500	2,000	6,200
March	980	3,500	6,000	10,400
April	980	3,500	6,000	17,000
May	980	3,500	4,000	9,600
June	980	3,500	4,000	5,000
July	980	3,500	3,500	3,000
August	980	3,500	3,500	2,400
September	980	3,500	3,500	2,200
October	980	3,500	3,500	3,000
November	980	3,500	3,500	3,000
December	980	3,500	2,000	5,400

*Note: figures shown are flow rates considered satisfactory for purposes shown. The values presented, however, are not additive. For example, a flow rate of 6,000 cfs in March would satisfy not only the anadromous fish program requirements but those also for water quality and hydroelectric power.

SECTION D

FORMULATING PLANS

1. The formulation portion of the study involved the investigation of alternative solutions for resolving the problems and fulfilling the needs that have been defined in the study area. Such alternatives were then screened to arrive at a plan that best responds to the problems and needs of the area. Plans were formulated so as to improve the quality of life through contributions to the objectives of national economic development and environmental quality.

2. Plans were developed for two time periods. The first -- or short range plan -- includes those additional actions necessary to insure an adequate water supply through the year 1990. The second time period -- the 1990 - 2020 era -- is considered long range in nature. Because the 1990 - 2020 plans are subject to a number of variables such as population and water use changes, as well as potential new technologies, the plans described later for this time frame are not "set in concrete." Rather, as described later, this report investigated all options based on the present state of the art. The direction which this analysis yielded is subject to change, of course, as new information becomes available. However, with today's knowledge, the potential of the various water supply sources is reported.

3. All projects, determined to be needed to insure that water supply demands are always met, were analyzed individually and in combination to arrive at the best course of action to solve the critical area's problems. Four key tests have been applied to all data:

> Reliability: Assure adequate quantity and quality of water supplies during conditions of severe drought.
>
> Flexibility: Be capable of being altered to accomodate future changes in the location and size of water supply demands, and economic, environmental, social and technological conditions and efficiently meeting fluctuations in demand over any given time period.

Timeliness: Meet water supply and other needs in a timely fashion and provide for orderly development of projects to meet additional water supply demands in the future.

Equity: Provide for the equitable distribution of natural resources and distribute in a reasonable and logical manner the economic, social and environmental costs of providing adequate water supplies and compensate equitably those who relinquish water or land rights to meet the water demands of others.

FORMULATION AND EVALUATION CRITERIA

4. To insure that the plan developed considered the full range of options, formulation and evaluation of all plans were based on technical, economic and intangible criteria such as possible environmental effects and social and political acceptance. The application of such criteria permits selection of a plan which best addresses the planning objectives, is socially, politically and environmentally acceptable, and economically justifiable. Once comparable level water supply plans had been developed, each alternative was evaluated for its cost and its effects on economic development and the quality of the environment in accordance with the Principles and Standards for Water Resources Planning and Related Land Resources. The beneficial and adverse effects of the alternatives were outlined and compared. Where possible, the alternatives were modified to reduce adverse effects.

TECHNICAL CRITERIA

5. The following technical criteria were developed for use in this study:

a. Water supplied would meet existing public health standards for potable water. To this end, a water treatment plant study was undertaken to determine the unit processes required to produce such water using the Merrimack River as a source of supply under both existing and forecast water quality conditions. Because of the existing water quality conditions, use of the river in its present state represents a degree of risk, however, implementation of the EPA-State programs for wastewater collection and treatment, the requirement of PL 92-500 and the Safe Drinking Water Act, should insure a higher quality water with less risk associated with its use for water supply in the forseeable future.

b. Pipes and pumps designed to meet short term needs were sized to carry the anticipated 2020 maximum day demands.

c. Tunnels for long range needs were sized to provide a dependable yield using anadromous fish and hydroelectric flow requirements as control flows.

d. Water distribution system pressures were designed to operate between a minimum of 40 pounds per square inch (psi) and 110 psi.

e. Long range tunnel aqueduct pumping requirements were designed to match the elevation of existing MDC system aqueduct at points of connection.

f. Secondary roadways were chosen to be the location of all proposed pipelines.

g. Proposed water treatment facilities would be located above the standard project flood level, and consideration would be given to nearness of transportation facilities, availability of land, room for expansion and proximity to the river.

h. The existing MDC system was assumed to form the nucleus of an expanded regional system for long range needs.

ECONOMIC CRITERIA

6. The economic criteria applied in formulating a plan are those found in the Water Resources Council -- Principles and Standards for Planning Water and Related Land Resources.

7. All of the alternatives were based upon July 1975 prices with annual costs based upon a 50-year period of analysis and an interest rate of 6 1/8 percent. Annual costs include interest and amortization, operation and maintenance, power costs and major replacement.

ENVIRONMENTAL AND OTHER CRITERIA

8. The following environmental and other criteria were considered in formulating a plan:

a. The utilization of an interdisciplinary approach to insure the integration of the natural, physical and social sciences in the plan formulation and selection process.

b. An evaluation of the effect which withdrawals of water may have upon the downstream flora and fauna. To accomplish this, two investigations were undertaken by consulting firms to determine the effect of withdrawals upon the river with special emphasis on the anadromous fish restoration program; and, upon the estuary with special emphasis upon the upstream intrusion of saline water due to decreased river flows.

c. An evaluation of the effects of possible upstream reservoir storage on the reservoir area itself as well as downstream river reaches.

d. An evaluation of the effect of large ground water withdrawals from Plymouth County.

e. Avoidance, where possible, of detrimental environmental effects, and inclusion of feasible mitigating features where necessary.

f. An evaluation of the social impacts generated by providing adequate water supply to a region was conducted. These impacts ranged from general policy considerations such as regional growth to specific impacts upon areas due to introduction and/or enlargement of water treatment facilities.

g. General public acceptance of possible plans, as determined by coordination with interested Federal and non-Federal agencies and various groups and individuals by means of public meetings, progress meetings, field trips, letters and other procedures.

SECTION E

FORMULATING ALTERNATIVE PLANS FOR THE SHORT TERM

1. All of the possible solutions to the needs of the short term study area may be broadly categorized as either non-structural or structural measures. Non-structural measures include such diverse methods as policy of No Development, consumer education, use of water-saving devices, weather modification, and waste water reuse. Structural measures include such diverse methods as use of the Merrimack River as a source of supply for the region, desalination, and local option available to the communities.

NON-STRUCTURAL MEASURES

NO DEVELOPMENT

2. The no development option is not an attractive alternative if one desires adequate fire protection, possibility of wet process industries to either locate or expand, growth, or in the least, no bans on water usage. The above items are not all inclusive of the restrictions and hardships which may befall a region due to lack of a dependable and potable water supply, they are merely examples of the types of problems which can be expected.

3. Two communities are worthy of examination with respect to this problem of lack of water supply--Lowell and Stoughton. Lowell has estimated that about 6,900 new jobs have been delayed because of the restrictions on water use which have had to be placed on the users due to lack of treatment capacity. Because the current unemployment rate in the Lowell area is 12.8% of the 107,300 total work force, it is apparent that this holdup in new employment opportunities is severely damaging to the region's economy.

4. Stoughton has been actively engaged in seeking additional water supply since 1955, and this search has disrupted other vital town functions. These functions include delaying construction of a new junior high school with the result that the old facility has forced double sessions due to lack of space; a sidewalk construction program has been delayed indefinitely and new road construction and repair has been greatly curtailed. An agreement with two nearby towns has assured adequate fire protection which had been lacking. No industries have been forced to move due to this water shortage; however, new industries have been turned away and no expansion of existing wet process industries is allowed. This has caused a stabilization in the tax base, with increased property taxes being the only way to offset the disperity between rising municipal costs and the leveled tax base.

5. Thus, based on the experiences in these communities, it would appear that the No Development option is not a viable alternative for this region.

WATER DEMAND MODIFICATION

6. Historically, municipal and industrial water usage, that is the amount of water used per day, has increased annually primarily due to increased industrial output and greater numbers of, and a wider distribution of, water consuming appliances and an overall higher standard of personal hygiene. This increase in usage, coupled with increased population, places great demands on what is, essentially, a fixed natural resource. At this point in time, with world-wide concern focused on food production and consumption, it may be beneficial to realize that the amount of fresh water available each year does not vary greatly and that this resource, too, is finite. In the study region, increasing the source of water supply is generally a question of economics--does a community or group of communities desire to have unlimited water and pay for it through increased water bills/taxes; or accept the inconveniences and possible hardships imposed by water restrictions and pay a smaller water bill? In most instances, the cost of water amounts to such a small expenditure when compared with per capita income, that the increase in supply is opted for. A number of people, however, have suggested that the increases in water demand can be slowed and some even suggest stopped if proper water demand management techniques were employed. In response to this interest, this study conducted investigations in the potential which water demand modification has in meeting future water supply needs. Methods tested for their potential in modifying water supply demands included:

a. water use conservation education programs
b. pricing policies
c. use of water-saving appliances and manufacturing processes
d. institutional restrictions on water use
e. leak detection and maintenance programs

7. The water demand modification study* concluded that there was no strong evidence that large quantities of water were being wasted in the study area. However, the study also noted that the phenomena is poorly understood and research be undertaken to yield information regarding the causes of leaks in water supply systems. Institutional restrictions on water uses were not found to be an attractive alternative to modify demands within the study area. Of all the institutional restrictions examined, only metering has historically reduced demand. In the study area, most communities are already metered, thus, institutional restrictions were ruled out. Pricing policies were initially thought to be the key issue in demand modification techniques. The study showed that price does not influence demand within the range of equitable prices. That is, such a large price would have to be charged for water in order to effect a demand reduction, that serious questions of equity would be raised. The price would far exceed the cost to develop, treat and transmit the water, and what should be done with the excess funds? Therefore, pricing policies were eliminated from consideration. However, there are a number of ways that water could be conserved. Most of the individual water-saving methods considered would have an insignificant effect if that method was the only conservation effort. The most promising technique consisted of a consumer education program covering a broad spectrum of methods combined with the installation of water-saving appliances. As a result, water demand conservation techniques were considered in the plan selection process given in Section E.

WEATHER MODIFICATION

8. The primary source of the water used for public and private water supply in Massachusetts, as in most humid areas, is precipitation falling directly on the areas concerned. It follows then that if precipitation can be increased in a regulated manner, the water supply

* <u>Water Demand Study Eastern Massachusetts Region,</u> prepared for the New England Division, Corps of Engineers, by Coffin & Richardson, Inc., Boston, Massachusetts, November 1974

can also be increased. To this end, several major agencies such as the National Oceanic and Atmospheric Administration (NOAA), the United States Bureau of Reclamation, the American Meteorological Society, and the National Science Foundation are investigating ways of productively modifying natural precipitation patterns. The primary focus of research is in the area of cloud seeding. Other fields of interest are long-term seasonal precipitation forecasting and fog drip augmentation. Since little work has been done on the latter two, and what little has been accomplished is not applicable to the Massachusetts area, only the process of cloud seeding will be reviewed in this section.

9. Simply stated, rain falls from clouds when water vapor in the clouds condenses around nuclei and forms rain drops large enough to overcome frictional resistance to falling. In technical terms, this process is the conversion of the water vapor from a state of colloidal stability to one of colloidal instability. The concept of artificially induced precipitation by cloud seeding refers to the introduction of particles of foreign substances, such as dry ice and silver iodide into clouds to serve as condensation nuclei. Theoretically, this action will result in condensation of the water vapor and consequent precipitation. In short, it is scientific rain making.

10. The testing of the engineering and economic feasibility of this theoretical process has been concentrated in experimental projects in the Rocky Mountain and Upper Great Plains regions. Evidence gained through NOAA research suggests that winter cloud systems over Lake Erie may be modified to produce additional precipitation. A cost benefit study was performed for the Connecticut River Basin, but this study was in design only with no actual experimental work involved. Most information regarding the potential of cloud seeding in the eastern United States is derived from commercial cloud seeding operations.

11. Research has continued to improve the state of the art of weather modification by cloud seeding and other means. At best, however, weather modification is still an inexact science. Studies are unable to predict optimum cloud conditions and seeding results with any degree of accuracy. It is the conclusion of this section, therefore, that at this time, weather modification operations to augment water supplies in Massachusetts do not appear to be a viable solution to the short term water supply problem.

WASTEWATER REUSE AS A MUNICIPAL SUPPLY

12. Waste water reuse, especially in industrial process application, has been economically successful in many sections of the country. The Bethlehem Steel Company in Baltimore, Maryland, currently uses about 120 mgd of treated municipal waste from Baltimore and uses this effluent in its quenching and cooling process. The Dow Chemical Company uses treated sewage from the City of Midland, Michigan, for use in its cooling water and fire protection system. In Amarillo, Texas, effluent from the municipal sewage treatment is used as cooling water and boiler make-up water for industries located in that city.

13. Other uses to which treated waste water has been applied include irrigation of both crop land and lawns, as a fresh water barrier against salt water intrusion, and in some cases as a source of supply for formation of recreation lakes and ponds. Direct reuse of waste water effluent as a public water supply, however, has not been utilized to a large degree. Advanced waste treatment research and development programs at the Federal level are continuing and pilot plant studies such as the noted Lake Tahoe project are apparently meeting with success in producing a high quality effluent.

14. The current Drinking Water Standards do not apply to direct reuse of reclaimed water for drinking. In a series of recent articles, the Division of Water Supply Programs, Environmental Protection Agency, (formerly Public Health Service) has described a number of potential health problems which could occur with the use of renovated waste water. Health officials feel that many questions remain unanswered which must be fully investigated if renovated waste water is to be considered for drinking water purposes. Research considered vital was described in an article * prepared by the Director and Deputy Director, Division of Water Supply Programs. In their article, it was stated that "before development of intimate personal-contact uses of renovated waste waters, one needs to:

a. Initiate studies on viruses for:

1) Development of improved viral detection and enumeration methodology.

2) Exploration and definition of the basic properties of enteric viruses.

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* Lang, W.N. and Bell, F.A., "Health Factors and Reused Waters," Journal American Water Works Association, April 1972.

3) Provision of knowledge on transmission of viruses through the aquatic environment.

4) Definition of the impact of viral disease on man through associated epidemiological studies.

5) Development of technology for the positive removal and inactivation of viruses.

b. Investigate the potential problems from bacteria and other microorganisms in reclamation systems.

c. Identify and define the potential health effects of organic and other chemicals not removed by reclamation plants and subject to build-up, and develop techniques to identify and measure readily the concentrations of such chemicals.

d. Dispel the cloud that hangs over the whole subject of reliability for wastewater treatment plant operation. Reclamation plants for direct reuse must have fail-safe processes, back-up facilities, alternate means for disposal, continuous monitoring, and bioassay, and they must be operated in an atmosphere that demands reliability. State programs responsible for the operation of wastewater treatment plants will require upgrading. Pilot and field-scale testing will be required for the validation of processes and practices prior to their widespread use.

e. Use common sense. Renovated wastewater should not be used for the ultimate personal use--as a drinking water supply--until there is no other practical choice; and then, hopefully, the minimum research will have been completed and the use will be carefully operated and controlled. Meanwhile, in water short areas, the renovation and reuse of wastewaters for industrial, limited irrigation, and other low human contact purposes should be investigated and advanced.

15. The future of direct wastewater reuse, particularly in industrial applications, seems promising. Future water demand forecasts for industrial usage used in this report, in fact, anticipates greater recycling of water in the industrial sector. Use of renovated wastewater as a regular domestic supply, however, requires full results of proposed research. Until such research is completed, wastewater reuse as a municipal water supply is not a viable alternative to meet short-range supply needs.

STRUCTURAL MEASURES

MERRIMACK RIVER AS A SOURCE OF SUPPLY

16. As described earlier in Sections A and C the Merrimack River Basin within Massachusetts appears to offer a potential source for meeting in-basin community supply needs for the short and long term and also holds promise as a long term source for out of basin municipalities within eastern Massachusetts. As a result of the longer range potential which the river may have all of the alternatives investigated for the short term were evaluated for their consistency with longer range alternatives. In turn, the potential of initially developing the basin with facilities designed to meet long term needs and utilization of these facilities to furnish short term needs in the interim period was also considered. All studies, however, indicated that early implementation of long range facilities would not be a cost effective solution for the short term.

17. Three separate regional alternatives were considered with the Merrimack River as the source of supply: the first two dealt with the communities identified as requiring additional water supply by 1990 within the Merrimack River Basin in Massachusetts; the third considered in-basin communities in New Hampshire. The Massachusetts communities identified were: Acton, Amesbury, Andover, Bedford, Billerica, Boxford, Carlisle, Chelmsford, Concord, Dracut, Dunstable, Georgetown, Groveland, Haverhill, Lawrence, Littleton, Lowell, Merrimack, Methuen, Newbury, Newburyport, North Andover, Pepperell, Rowley, Salisbury, Tewksbury, Tyngsborough, Westford and West Newbury. The New Hampshire communities considered were Atkinson, Hampstead, Salem, Windham, Amherst, Brookline, Hollis, Hudson, Litchfield, Lyndeborough, Merrimac, Milford, Mont Vernon, Nashua, Pelham, and Wilton. A plan of these communities is shown on Plate 13.

18. A Water Treatment Plant Study * was undertaken to determine the unit processes which would best treat the waters of the Merrimack River. The study also reported on locations for a plant, and selected a site in Tyngsborough on the western bank of the river. The site selection process included the availability of railroads; the site must be above the flood of record; the site must have room for expansion; be at a river reach to afford the highest quality water possible; and provide for the least number of river crossings possible.

19. Transmission mains were sized to carry the anticipated maximum daily demands of the year 2020. The transmission system was analyzed using a modified Hardy Cross technique on a digital computer. The minimum pressure allowed was 40 pounds per square inch, and a pressure of 100 pounds per square inch was opted for as a maximum. Headlosses within the system were kept less than 1 foot within the looped portion of the system. With these design restraints, pipe sizes were determined and pumping stations placed to optimize the system.

20. Construction costs were determined and based on July 1975 price levels. Annual costs were calculated based upon a 50-year project life at 6 1/8 percent interest rate; major replacement costs which were anticipated; and operation and maintenance.

21. The following projects were considered:

a. One regional water treatment plant located in Tyngsborough serving all of the water deficient communities within the basin in Massachusetts. The demands to be met by the system were those demands anticipated in the design years minus the present safe yield of each individual community system.

b. Two regional plants serving the same in-basin communities as Alternative 1; however, the existing Lawrence Water Treatment Plant was expanded to accommodate all communities, north and east of Lawrence. The aforementioned plant at Tyngsborough would service all of the other communities; it would, however, be reduced in size.

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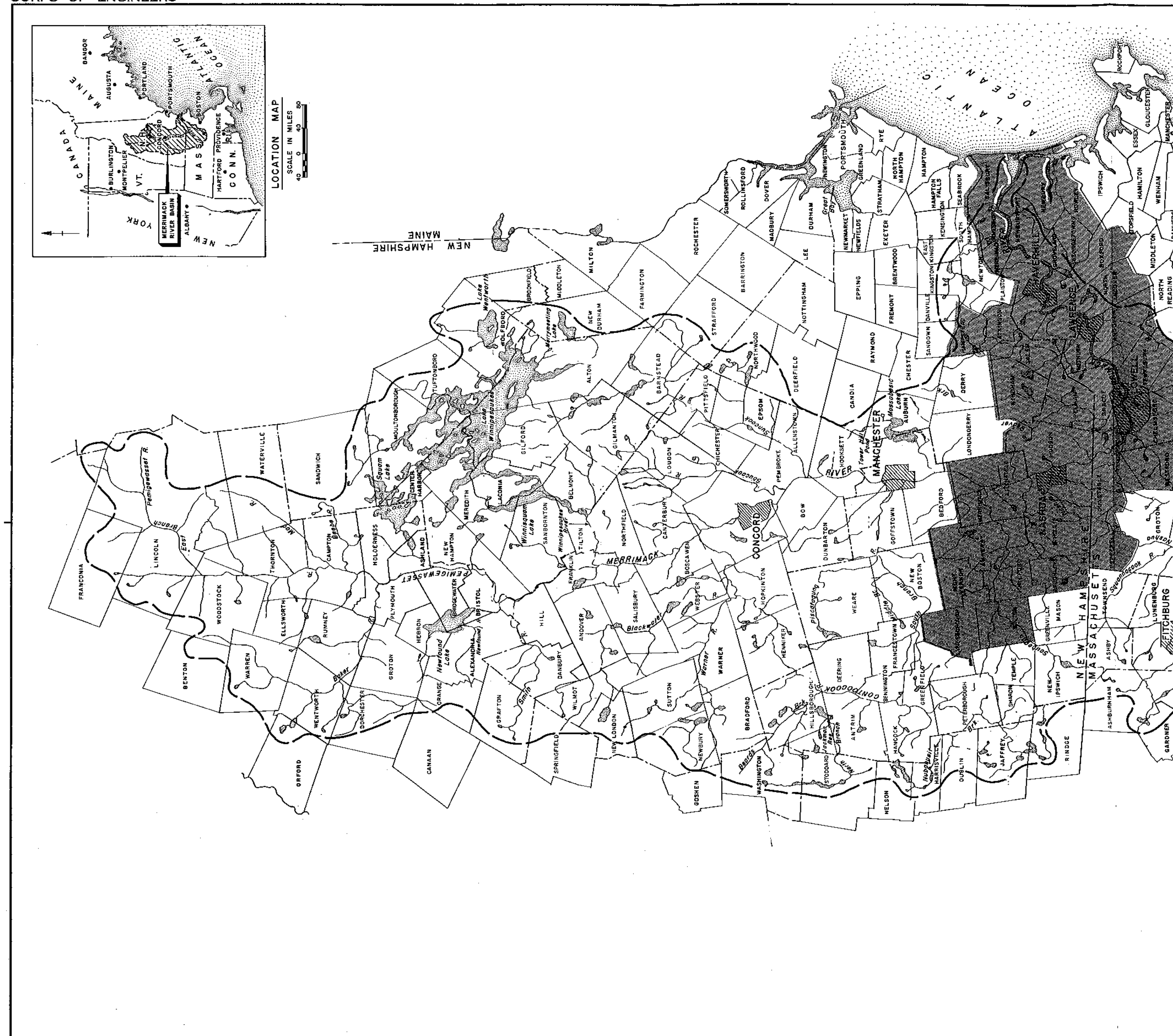
* Water Treatment Plant Study, Merrimack River, Massachusetts, prepared for the New England Division Corps of Engineers, by Hayden, Harding & Buchanan, Inc., March 1975.



NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

MERRIMACK RIVER STUDY

COMMUNITIES CONSIDERED AS POSSIBLE CANDIDATES TO BE SERVED BY REGIONAL SYSTEMS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

c. This alternative considered serving the Nashua regional area and the Salem regional area from the basic Massachusetts system. The Massachusetts system would be whichever one proved to be the most economical and have the least environmental impact of the two previous alternatives.

22. The Nashua Regional Planning Commission has had a water management study done which recommended use of the Merrimack River as a regional source of water supply. Because the Sub-Regional System had the lowest construction cost, it was used as the basis for comparison with the Nashua system. The comparison was between an expanded water treatment plant in Tyngsborough and transmission main to Nashua and a treatment plant in Nashua. The construction cost for the short term needs indicate that the Nashua Regional plan is less expensive than an addition to the Tyngsborough plant and transmission main.

23. The Sub-Regional System was also used to compare costs with the Salem, New Hampshire water supply options. For short term, it is less expensive for Salem to augment its own supply than it is to pay for an expanded Lawrence water treatment facility and transmission main.

DESALINATION

24. Desalination, the process in which brackish and salt water is converted to fresh, is currently being used in some parts of the world as a viable, economically feasible source of fresh water. This process thus was considered for its potential as a future alternative solution to the water supply needs of eastern Massachusetts and southeastern New Hampshire.

25. The conversion of saline to fresh water is accomplished through four major processes: distillation-evaporation, membrane separation, crystallization, and chemical differentiation. Sea water can be considered, for all intents and purposes, an unlimited source of fresh water once the technology of desalination is refined to a point where it is economically feasible. To this purpose, the federal government, through the Office of Saline Water, has promoted extensive study and

research into the problems of desalination. Several model and testing plants and facilities have been constructed to aid in these studies. The research to date concludes that of the four main processes discussed above, distillation and membrane separation are best suited to large capacity plants. Economical considerations dictate that distillation is best for sea water and electrodialysis for brackish water.

26. Presently more than 300 million gallons per day (mgd) of desalting capacity are installed world-wide. Plants are generally located in arid regions where conventional water sources are high cost or unavailable. Principal areas of use are in the Mid-East and Caribbean tourist islands. In the United States, desalting for municipal water supply has thus far been limited to smaller communities, relatively isolated from sources of conventional supply.

27. The cost of fresh water produced by desalination depends upon the capacity of the plant, the type of process used and whether nuclear or fossil fuel is used. In general, the larger the plant capacity, the less the cost per unit of water. As has been mentioned previously, distillation is more economical for the desalting of sea water, while electrodialysis is better for brackish water. The water costs from nuclear fueled plants are approximately 10% less than from fossil fuel when used in large capacity (more than 100 mgd) plants. Designs for larger plants, such as for a proposal for San Louis Obispo and Santa Barbara Counties, California, indicate costs in the vicinity of 73 cents per thousand gallons at the plant site. To this figure must be added delivery system costs.

28. Recent reported experiences in Hong Kong * and in Key West, Florida** indicate that operational costs of desalting are increasing beyond tolerable limits. Hong Kong authorities have discarded plans for expanding their existing desalting plant, specifically designed for modular expansion, and have planned a $290,000,000 reservoir diversion tunnel, and water treatment plant expansion on the mainland. Costs for desalting would have been $92,000,000 for capitol outlay plus an annual cost of $11,000,000 for chemicals and fuel oil alone. Therefore, the existing 40 mgd desalting plant will stay on line to meet short term needs until the new reservoir is completed and filled, which is expected to happen in 1978. Key West, Florida has experienced an increase from $0.85 to $3.60 per thousand gallons

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* Engineering News Record, January 16, 1975

** Engineering News Record, July 31, 1975 of water treated at its 2 mgd desalting plant at Marathon, Key West. The increase in operational costs was caused by the sharp rise in fuel, chemicals, and maintenance costs, and are the reasons why an additional desalting plant is not being considered at this time.

29. In summary, desalination by numerous processes is already feasible in parts of the world when the natural water supply is either scarce or of poor quality. In these areas, the relatively high costs of water produced by desalination are justified. Research * has indicated that when larger capacity plants are designed and in production, the costs for desalting sea water could ultimately be reduced to approximately 50¢ per thousand gallons, although the proposed California plant would produce water at 73¢ per thousand gallons at the plant site. Even at this reduced cost, however, desalination is not competitive with present costs of developing natural surface and subsurface water supplies.

30. Aside from the economic costs involved with desalination, the Office of Saline Water is also investigating the potential hazards to the environment which might occur. In considering placement for any type of desalting plant, environmental factors are as important as any other factor. Pure water is not the only product. A plant will produce extremely concentrated brine as an effluent, plus any waste products from the power source, such as soot, heat, smoke, toxic gasses, etc. So far as brine is concerned, this brine from distillation plants is of high temperature, higher chloride content and may contain concentrations of copper, all of which may prove injurious to the environment. Special design procedures would be required, in the cases of estuaries or areas with restricted water interchange, as many life forms present might be adversely affected. Two land methods of disposal have been studied: (1) evaporation to dryness; and (2) deep-well injection. Evaporation is expensive, though this is highly dependent on land costs, presently quite costly in urban areas. Injection method costs are estimated at 25 to 70 cents per 1,000 gallons of brine. Such costs must be added to plant production and distribution costs to arrive at a true cost of water from this technology. At present, the Office of Saline Water is investigating other methods of brine disposal.

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* Based on data contained in memorandum from Office of Saline Water to New England Regional Coordinator, U. S. Department of the Interior, 17 August 1972, (1972 price levels).

31. The future of desalting in the northeast is described as follows by the Office of Saline Waters:*

> "Existing desalting operations are characterized by several constraining features. Among the most important are high total annual costs, relative to conventional water sources; the need for proof of large-scale plant operation; and the problem of brine disposal. In the future, as technology is further developed, several of the constraints will be lessened, and desalting may prove to be an attractive supplement to water supply in coastal and estuarine areas of the Northeast United States. Desalting processes may also serve future use as an aid in control of water quality".

32. As a result, this report concludes that desalination not be considered at this time as a viable alternative source of water in the Merrimack Basin for the short-range water supply problems. When and if the technology and efficiency of this process is refined so that it is economically and environmentally competitive with other methods of supplying water, its feasibility can be re-evaluated.

IMPORTATION

33. During the crisis years of the sixties' drought, many newspaper and periodical articles pondered the possibility of diverting water from extra-regional sources as a solution. One of the major basins often mentioned as a water supply source for the Northeast was the Saint Lawrence. As an alternative to developing local resources to meet future water needs, an investigation was made regarding the feasibility of diverting Saint Lawrence flow to meet future needs.

34. The Saint Lawrence River Basin is an impressive basin, both in its size and the annual runoff from its watershed. The drainage area is about 295,000 square miles at Ogdensburg, New York, which includes over 95,000 square miles of water surface area, most of which is in the five Great Lakes. Storage capacity within the lakes regulates the flow in the river to a large degree. The long term average discharge at Ogdensburg is about 240,000 cubic feet per second (155,000 mgd). From a review of these statistics, it is apparent that the basin, if developed, could meet the forecast supply demands for not only the Merrimack Basin, but all of southeast New England.

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* Ibid.

35. Engineering studies were conducted to assess various methods and quantities of development from the basin. Cost estimates were prepared for projects which would service all of the Northeast through the year 2020. Construction costs for such facilities were estimated to be as high as 8.5 billion dollars, excluding any necessary water treatment costs. Water delivered from such an undertaking would cost substantially more than similar volumes made available from local resource potential, and it was not considered a viable alternative.

DUAL WATER SUPPLY SYSTEMS

36. An alternative which has been receiving attention of late has been the use of dual water supply systems. In these systems, a hierarchy of water supply would be established whereby higher quality supplies could be used to furnish a potable source for drinking, cooking, dish-washing, cleaning, bathing and laundering. All other uses could be furnished by a second supply of lesser quality.

37. Two general methods have been suggested for such a dual system. The first is the possibility of recycling at the point of usage. Under this scheme, drinking, washing and bathing water would undergo treatment and then be further utilized as toilet flush water and outdoor uses. It is estimated that such a system could reduce domestic water use by as much as 50%. Various systems for in-house reuse or for outdoor usage have been proposed and some are being marketed on a small scale.

38. Advantages to this system beyond potable water consumption reduction are the reduction in sewage water volume, sewer pipe and pumping requirements. Capital cost outlay for such a system based on limited cost data would be over twice as expensive as water delivered from this report's recommended project. Other dis-advantages to this alternative lie with its limited application and accompanying operational experience, potential problems of odor and other aesthetic considerations. Health officials, in general, have not expressed their acceptance or rejection of such systems. However, their general apprehension in introducing less than potable water into the home environment could also reasonably be expected with regard to any system of this nature.

39. The second method which has been suggested for delivering higher and lower quality water for various uses would require a second distribution system. This second distribution system would carry river water or even sea water to supplement the high quality primary supply source.

40. Two methods of providing the second (lower quality) distribution system could be employed. The first would involve installation of the entire system immediately. The second, and more practical method would be on an incremental approach wherein secondary systems are installed in new or replacement buildings above a certain size. The second approach was evaluated in this report. With this approach, water consumption is only reduced at a given time by the building construction that utilizes secondary systems.

41. To estimate costs for such a system, a report * on the New York City area prepared as part of the NEWS Study was utilized. Based on the results of that investigation, preliminary capital cost estimates for such a dual system would be approximately 6.5 million dollars per mgd saved. The alternative discussed in this report using the Merrimack River as a source would cost approximately 1.5 million dollars per mgd produced; therefore, this is not considered a viable alternative.

NO ACTION (BY FEDERAL AGENCIES)

42. In this alternative, the various cities and towns would provide for their future short term needs by development of locally available surface and groundwater resources. No overall regional system would be constructed and therefore Federal involvement would be expected to be minimal. In essence, this alternative is a continuation of current practice. That is, cities and towns provide their own facilities with their own funds. In some cases, several communities may join in the development of a source, but no overall regional scope action takes place.

43. Many of the study area's communities have conducted investigations of their surface and groundwater resources in an effort to provide for their future needs. All available reports and studies were reviewed and the recommended water supply components were incorporated into the so-called "No Action" plan.

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* Anticipated and Emerging Advances in Water Supply Technology, International Research & Technology Corporation, February, 1972.

SHORT TERM ALTERNATIVES CONSIDERED FURTHER

44. As a result of screening scope investigations, most of the possible short term solutions described in the preceding paragraphs were eliminated from further consideration. Those which were eliminated include no development, weather modification, wastewater reuse as a municipal supply, desalination, importation, and dual water supply systems. Alternatives considered further, therefore, consist of water demand modification, Merrimack River as a supply source, and the No Action (by Federal Agencies) plan.

WATER DEMAND MODIFICATION

45. As stated earlier, there are a number of ways in which water can be conserved which could extend the effectiveness of existing and future water supply systems. In order to determine which conservation methods would be effective, an inventory was conducted of existing water usage for a number of municipalities within eastern Massachusetts. Information on current usage and the quantities used for domestic, municipal, commercial, industrial and distribution losses was obtained from municipal operating personnel. However, the type of utilities that maintain detailed records by type of use is limited and there is wide variation in the definition of the classification of use. Sufficient information was obtained, however, to show general use patterns in the eastern Massachusetts region.

46. Overall, it was found that consumption, exclusive of industrial use, has been increasing at a rate of about 1.2 gallons per capita per day annually for at least the last decade. Although wide variations in the usage categories were found, the following breakdown of total production within the short range study area was considered appropriate:

Category	Percent
Domestic	61.5
Municipal	2.3
Commercial	6.2
Industrial	23.2
Losses	6.8
	100.0

47. At the outset of this report, pricing policy was considered to hold great potential as a demand modification technique. Extensive examination of this method indicates that pricing policy is not a very effective tool in reducing or controlling the demand for water. This conclusion is occasioned primarily by the current low cost within the region of water which represents only a small part of household and business costs. If substantial price increases were made to control demand, the water revenue would exceed dramatically the cost of services and severe questions of equity would surround such an increase.

48. Consumer education, on the other hand, when combined with use of water-saving appliances is considered to have a potential for reducing water usage. Use of water-saving toilets and shower heads, when these items are installed or replaced is economically sound. Although many of the manufacturers have water-saving models of toilets and shower heads, they report limited sales within eastern Massachusetts. A consumer education program designed to demonstrate the effectiveness of water saving devices as well as economically feasible modifications in existing appliances is considered necessary, therefore, to attain the full benefit of these devices.

49. The savings in water demand that could be attained by various methods are described fully in the earlier referenced Corps of Engineers Water Demand Study for Eastern Massachusetts. In the following table, the potential reduction is given as a percent of estimated demand without demand modification. For all of the methods shown, an education program would be necessary.

50. If the recommended demand modifications were implemented and the impact shown on Plate 14 and in the table fully realized, the reduction in the future short term water supply needs of the Merrimack Basin would be about 8 mgd; and by 2020, this figure could total 13 mgd. The effect of such reductions on the Merrimack River Basin communities identified as requiring additional water supplies by 1990 would not relieve those municipalities from increasing their supply sources. If the demand modification methods were successful, however, it would allow the new facilities to serve the communities' needs for about five years longer.

EFFECT OF DEMAND MODIFICATION TECHNIQUES ON ESTIMATED WATER SUPPLY DEFICITS FOR COMMUNITIES WITHIN THE SHORT TERM STUDY AREA

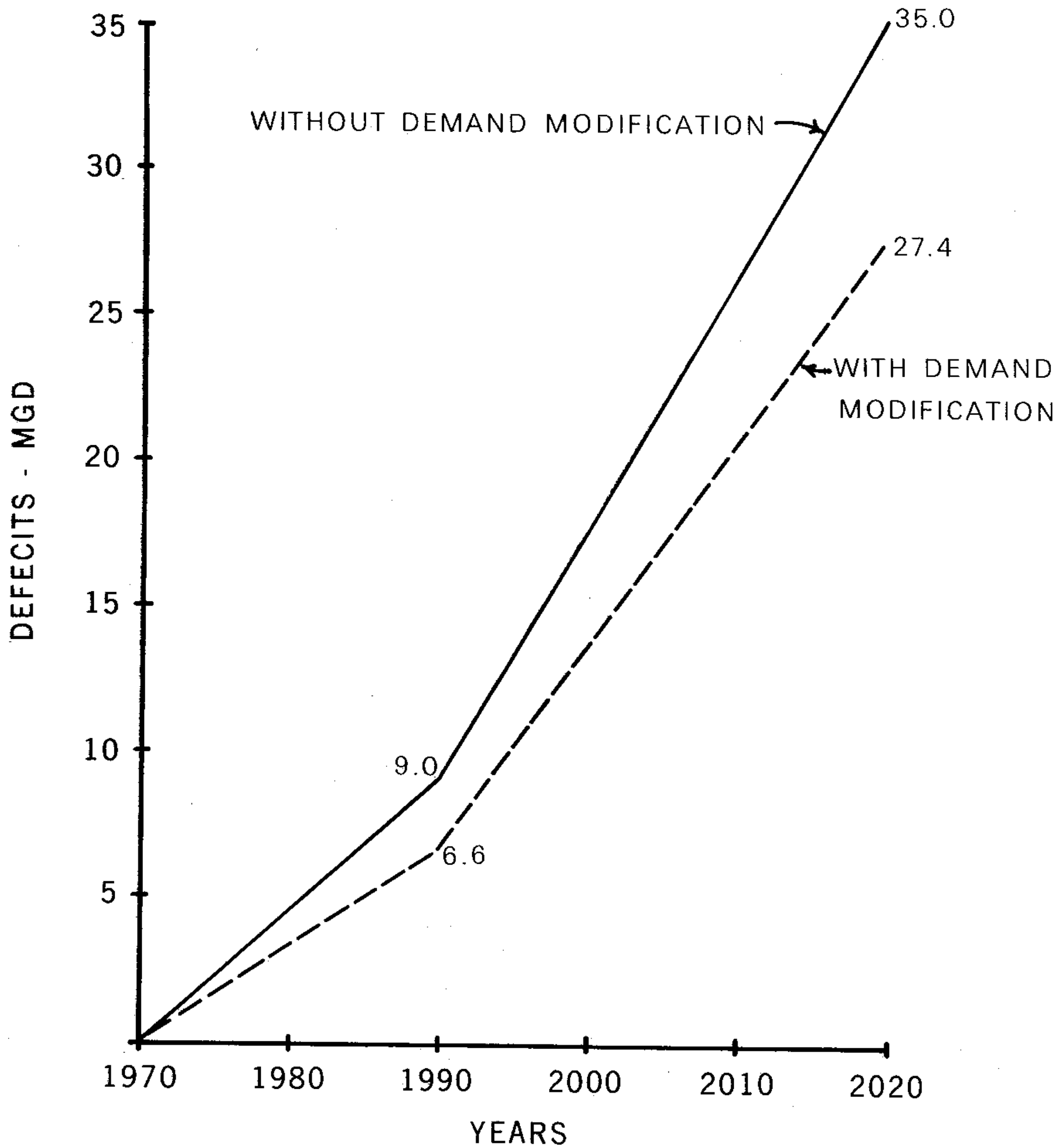


PLATE 14

Table E-1. Estimated Effect of Water Saving Methods

Water Saving Method	Estimated Percentage 1990	Savings 2020
1. Water Conservant toilets and showers for all new and replacement installations*	4.2	6.0
2. Installation of displacement devices in existing toilets*	2.2	1.6
3. Installation of flow control devices on sinks **	1.2	1.2
4. Modification of washing machines **	0.3	0.3
5. Modification of dishwashing procedures**	0.6	0.6
6. Elimination of food disposers **	1.2	1.2
7. Modification of commercial and home car washing procedures *	0.4	0.4
8. Meter all existing flat rate users*	1.5	1.5
9. Replacement of commercial and industrial flush-type toilets**	0.2	0.2
10. Replacement of grass areas with mulch**	1.0	1.0
11. Industrial reuse*	3.5	3.5
TOTALS	16.3	17.0

* Relatively easy to achieve.
** Relatively difficult to achieve.

REGIONAL SYSTEM

51. As illustrated on Plate 15, the Regional System would consist of a large water treatment facility located on the Merrimack River in Tyngsborough and would service all of the communities previously listed as requiring short term augmentation. The following assumptions were made:

a. The Lowell water treatment plant would expand from 10.5 mgd to 30 mgd and service those surrounding communities having an immediate need; implicit in this assumption is the necessity of this system being augmented by 1990 by the Regional System; i.e., Lowell would continue to service only Dracut after 1990.

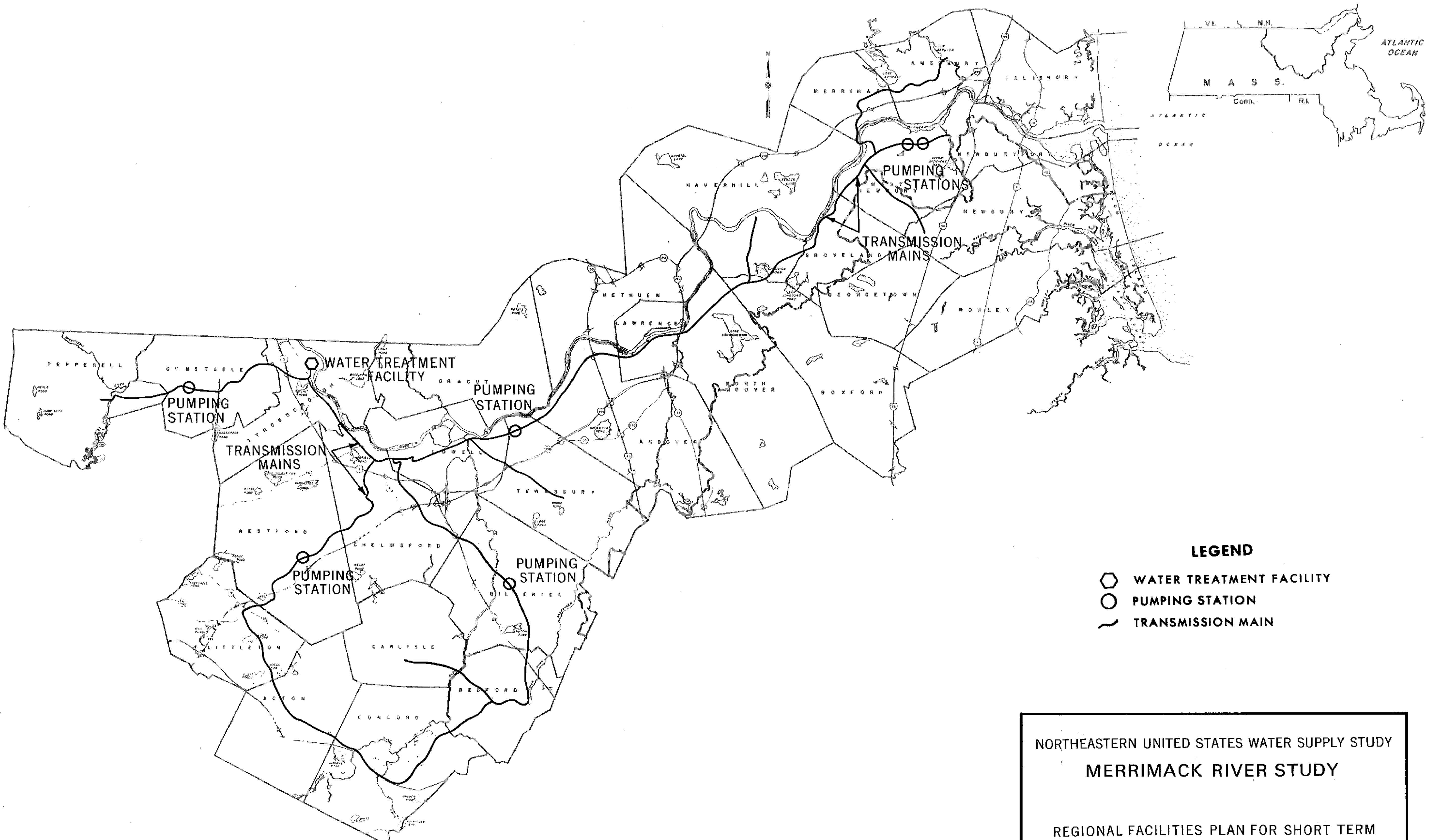
b. All demands over the present capacity of the Lawrence water treatment plant (14.5 mgd) for Lawrence and Methuen would be met by the Regional System.

c. Because of the lack of system storage, pipe sizes would be determined by the estimated 2020 maximum day demands; pumping station locations would be determined roughly by topographic and system characteristics; the sizing of the pumping stations would be determined by the estimated maximum day demands of each of the design years.

d. Haverhill would construct a 12 mgd water treatment facility to accommodate immediate needs; all demands over 12 mgd would be met by the Regional System.

52. The Regional System would be composed of the following transmission mains and pumping stations (as shown on Plate 15, all transmission mains would be lain in secondary roads):

a. From the water treatment plant in Tyngsborough, 0.7 miles of 66 inch diameter would be laid to the intersection of Routes 3A and 113. To service Dunstable and Pepperell, water would be diverted from this intersection through approximately 3.5 miles of 24 inch diameter pipe and 5.5 miles of 18 inch diameter pipe. A pumping station with a 3.6 mgd capacity would provide the lift necessary in the line. An additional 3.7 miles of 66 inch diameter pipe would be laid in Route 3A to the intersection of Richardson Road and Princeton Street in Lowell. From here, the "loop" communities of Chelmsford,



NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

MERRIMACK RIVER STUDY

REGIONAL FACILITIES PLAN FOR SHORT TERM

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 15

Westford, Littleton, Acton, Concord, Bedford, Carlisle and Billerica would be served by approximately 47.8 miles of transmission mains varying in size from 12 inches to 54 inches in diameter. A pumping station, with a capacity of 5.9 mgd, would be required in Hildreth Street, Westford; an additional pumping station, with a capacity of 10.5 mgd, would be required in Boston Road, Billerica. These two stations would insure minimum pressures of 40 psi throughout the loop system. Approximately 40.8 miles of transmission mains, ranging in size from 12 inches to 42 inches in diameter would service the remaining communities of Tewksbury, Methuen, Lawrence, Haverhill, Groveland, West Newbury, Newburyport, Newbury, Merrimack, and Amesbury. Pumping stations of 18 mgd, 3.4 mgd and 3.4 mgd capacities are required in Andover Street, Lowell, and Main Street, West Newbury, respectively.

53. Construction cost estimates for this system based on July 1975 price levels and an interest rate of 6 1/8% over a 50 year life are given in Table E-2.

SUB-REGIONAL SYSTEM

54. The Sub-Regional System, shown on Plate 16, would service the same communities as the Regional System, with the same basic assumptions; however, the expanded Lawrence water treatment plant would replace some transmission mains and reduce the size of others. The description of this system is as follows:

a. One treatment plant, sized at 28 mgd, would be located in Tyngsborough at the same site as the Regional System's plant. This facility would service the "loop" communities described in the Regional System. The mains, decreased in size, are: the 66 inch diameter main from the water treatment plant reduces to 54 inches in diameter for 0.7 miles of its length, and the remaining 3.7 miles of 66 inch diameter main is reduced to 48 inches in diameter. The 1 mile of 54 inch diameter main within the "loop" is reduced to 18 inch diameter main.

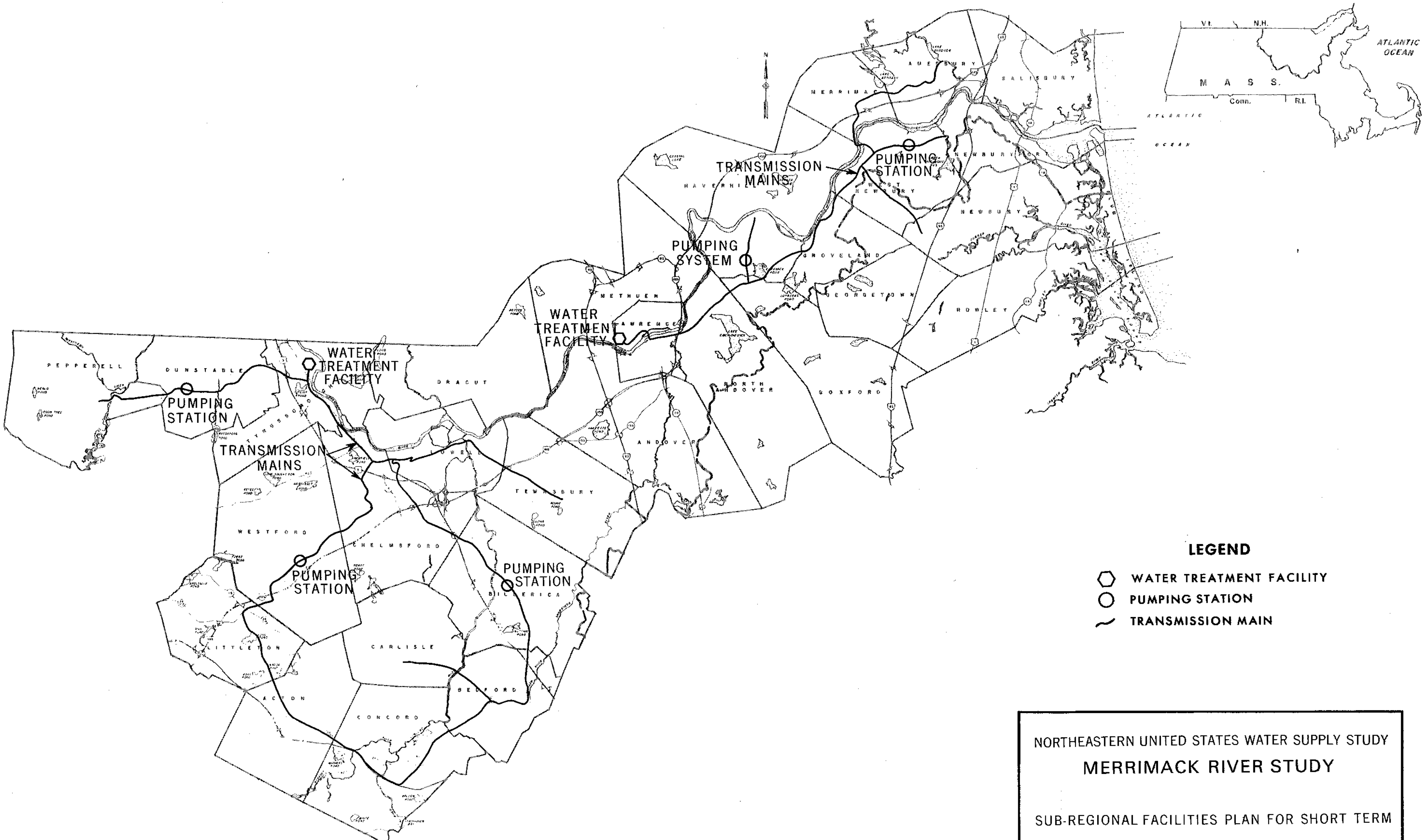
b. Of the 40.8 miles of transmission mains in the Regional System which service those communities from Tewksbury east to Newburyport, approximately 8.6 miles of 42 inch diameter main between Lowell and Lawrence will not be required. This main will be replaced by expanding the existing 14.5 mgd capacity Lawrence water treatment facility to 35 mgd capacity.

Table E-2. Regional System Construction Cost Estimates
July 1975 Dollars

Transmission System:	
12.0 miles of 12 inch diameter pipe	$ 1,984,000
4.5 miles of 15 inch diameter pipe	846,000
24.0 miles of 18 inch diameter pipe	5,525,000
15.5 miles of 24 inch diameter pipe	4,727,000
14.5 miles of 30 inch diameter pipe	5,240,000
14.0 miles of 36 inch diameter pipe	6,205,000
12.0 miles of 42 inch diameter pipe	6,804,000
1.0 miles of 54 inch diameter pipe	1,002,000
4.5 miles of 66 inch diameter pipe	5,267,000
Pumping Stations	2,646,000
Sub-Total, Transmission System	$40,246,000
Water Treatment Facility, 47 mgd capacity	
Intake Works	1,100,000
Rapid Mixers	230,000
Flocculators	1,300,000
Settling Tanks	7,000,000
Filters	5,400,000
Alum Recovery Plant	1,120,000
Carbon Regeneration Plant	750,000
Chemical Storage Building	1,250,000
Adm. Building, landscaping, etc.	1,850,000
Sub-Total, Water Treatment Facility	$20,000,000
Contingencies (20%)	12,050,000
Engineering and Design (12.1%)	8,750,000
Supervision and Administration (7.9%)	5,710,000
Sub-Total, Construction Costs	$86,756,000
Interest during Construction	8,400,000
Real Estate	229,000
Total Project First Cost	$95,385,000

Regional System Annual Cost Estimates
July 1975 Dollars

Interest and Amortization	6,157,100
Electrical Charges	984,000
Operation and Maintenance	1,696,075
Major Replacement	310,260
Total Annual Charge	$ 9,147,435



LEGEND

- WATER TREATMENT FACILITY
- PUMPING STATION
- TRANSMISSION MAIN

NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

MERRIMACK RIVER STUDY

SUB-REGIONAL FACILITIES PLAN FOR SHORT TERM

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 16

c. Pumping stations would be located and sized as follows:

1. The intersection of Routes 3A and 113 in Tyngsborough with a 60' head for a 3.6 mgd capacity.

2. Hildreth Street, Westford, with a 180' head for 5.9 mgd capacity.

3. Boston Road, Billerica, with a 70' head for a 10.5 mgd capacity.

4. Main Street, West Newbury, with a 30' head for a 3.4 mgd capacity.

5. Main Street, West Newbury, with a 124' head for a 3.4 mgd capacity.

55. Construction costs were estimated for this system, with July 1975 price levels used, and an interest rate of 6 1/8 percent over a 50-year life for the computation of annual charges. These costs are shown on Table E-3.

Table E-3

Sub-Regional System Construction Cost Estimates

July 1975 Dollars

Transmission System:

12.0 miles of 12 inch diameter pipe	$ 1,984,000
4.5 miles of 15 inch diameter pipe	846,000
28.0 miles of 18 inch diameter pipe	6,300,000
15.5 miles of 24 inch diameter pipe	4,727,000
14.5 miles of 30 inch diameter pipe	5,240,000
15.0 miles of 36 inch diameter pipe	6,715,000
4.0 miles of 48 inch diameter pipe	2,509,000
1.0 miles of 54 inch diameter pipe	585,000
Pumping Stations (Tyngsborough Plant only)	1,155,000
Sub-Total, Transmission System	$30,061,000

Tyngsborough Water Treatment Facility, 28 mgd capacity:

Intake Works	$ 860,000
Rapid Mixers	170,000
Flocculators	825,000
Settling Tanks	4,500,000
Filters	3,850,000
Alum Recovery Plant	825,000
Carbon Regeneration Plant	610,000
Chemical Storage Building	830,000
Adm. Building, landscaping, etc.	2,030,000
Sub-Total, Tyngsborough WTP	$14,500,000

Expanded Lawrence Treatment Facility to 35 mgd from 14.5 mgd:

Rapid Mixers	90,000
Flocculators	470,000
Settling Tanks	3,000,000
Filters	2,200,000
Alum Recovery Plant	345,000
Carbon Regeneration Plant	220,000
Chemical Storage Building	380,000
Adm. Building, landscaping, etc.	670,500

Table E-3 (Cont'd)

Modification to Existing Plant:

1. Raw water pumping station; pumps, inspection platform and stairway at the trash rack	$ 429,500
2. Substitution of rapid mixing for slow mixing and changes to raw water main piping	215,000
3. Modifications to five existing flocculating settling tanks	1,723,000
Sub-Total, Expanded Lawrence Treatment Facility	$ 9,743,000
Contingencies (20%)	10,860,800
Engineering and Design (12.1%)	7,885,000
Supervision and Administration (7.9%)	5,150,000
Sub-Total, Construction Costs	$78,199,800
Interest during Construction	7,571,700
Real Estate	613,000
Total Project First Cost	$86,384,500

Sub-Regional System Annual Cost Estimates
July 1975 Dollars

Interest and Amortization	5,576,120
Electrical Charges	959,000
Operation and Maintenance	1,521,310
Major Replacement	363,235
Total Annual Charges	$ 8,419,665

NO ACTION (BY FEDERAL AGENCIES)

56. Although this alternative is titled the "No Action" plan as described earlier, it should not be misconstrued to mean no additional facilities would be constructed. Rather the No Action plan indicates individual town and in some cases groups of towns developing local resources to meet their short range (1990) needs. Traditionally, however, this local approach has been carried on without Federal involvement.

57. The data presented here was garnered from such diverse sources as engineering reports, conversations with water supply personnel, and regional planning agency reports. All costs were adjusted to be comparable with the costs presented in the Regional and Sub-Regional sections of this report which were previously listed. To insure compatibility and comparability with the Regional and Sub-Regional, Corps of Engineers estimates for future water demands were made for all of the in-basin communities identified as possibly requiring source augmentation in the short term. The "No Action" or Local Option plan is illustrated on Plate 17, and the following is a description of each community's options:

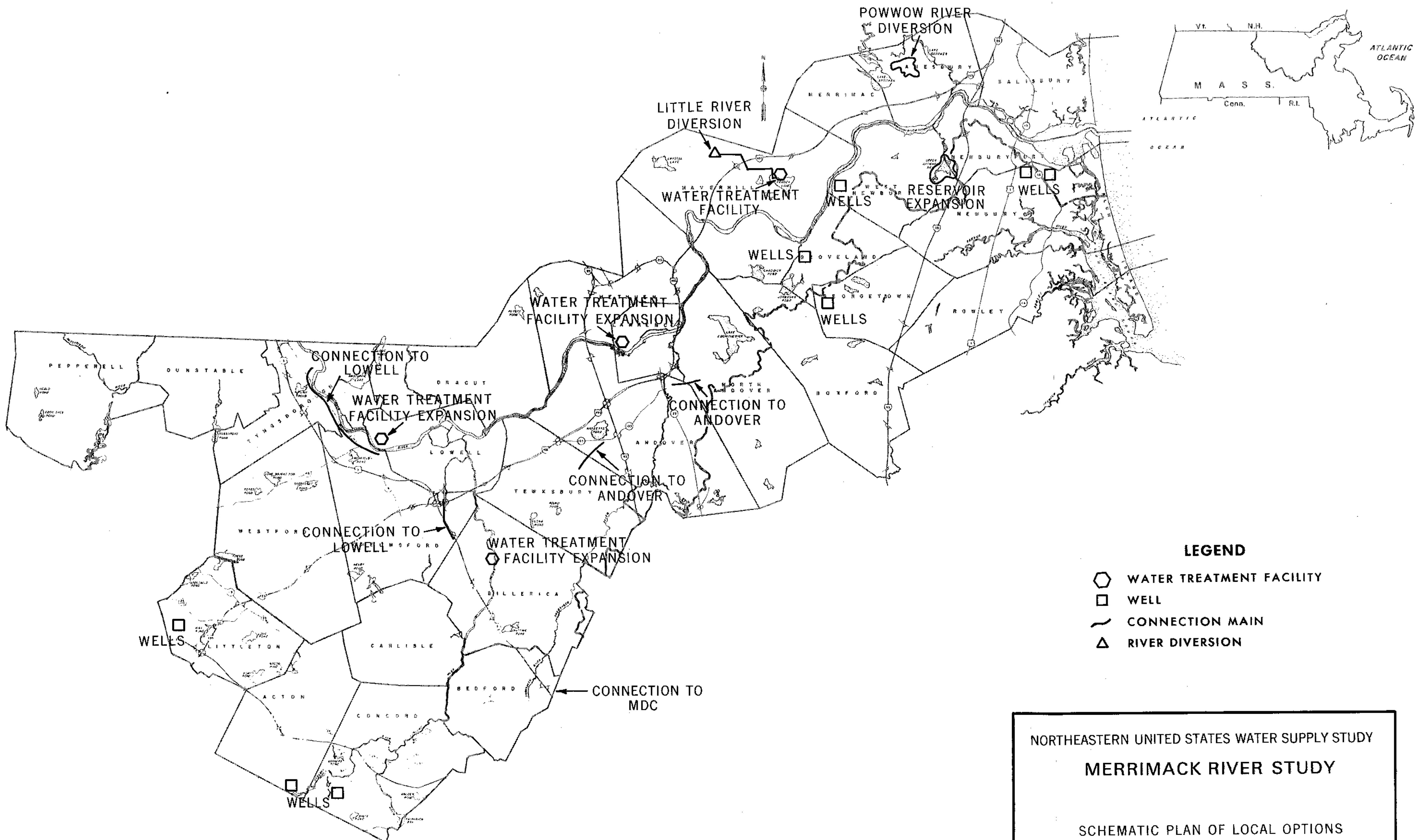
58. Groundwater Supplied Communities:

a. Pepperell--Groundwater is the present source of supply for this community. Although the present safe yield of existing groundwater sources is 1.7 mgd and the anticipated maximum day demand is 3.8 mgd, in the year 1990, the community feels certain that additional groundwater sources can be located to meet needs beyond the year 2020.

b. Dunstable--Small public water supply at present time. Most of community relies upon on-lot groundwater sources, and short term projections indicate trend will continue and be adequate.

c. Westford--Groundwater sources, with a combined existing safe yield of 4.8 mgd, supply the community's needs. The Corps of Engineers study indicates that an additional 1.8 mgd can be developed from groundwater sources. This development would meet the anticipated needs of this community through the year 2020.

d. Littleton--Existing safe yield of its groundwater supplies is 1.8 mgd which is the estimated 1990 average day demand for this community. A bond issue has been passed to fund an exploratory well



LEGEND

- WATER TREATMENT FACILITY
- WELL
- CONNECTION MAIN
- RIVER DIVERSION

NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

MERRIMACK RIVER STUDY

SCHEMATIC PLAN OF LOCAL OPTIONS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 17

program, and because of the Town of Ayer's recent establishment of a well near the Sandeville section, with an estimated safe yield of 2.0 mgd, the Town feels certain it can develop enough groundwater to meet its needs through the year 2000. Information currently available for Corps of Engineers review does not support this assumption, however the Town is certain groundwater is available in sufficient quantities to meet their needs.

e. Acton--Present source is groundwater with an existing safe yield of 2.75 mgd. Corps of Engineers study indicates that an additional 2.1 mgd may be developed from groundwater sources. This development would meet the community's average day demand through the year 2000.

f. Bedford--Groundwater sources, with an existing safe yield of 3.3 mgd, presently supply the community. A connection with the MDC has been reported possible, and such a connection would allow the community to meet its anticipated needs through the year 2020.

g. Carlisle and Boxford--Presently, no municipal water supplies are operated in these communities. It is anticipated that on-lot supplies will continue to meet the needs of these communities; however, should a municipal supply be developed, it is expected that groundwater would be available in sufficient quantities to meet the water supply needs.

h. Groveland and West Newbury--Groveland supplies West Newbury from its groundwater source which has an existing safe yield of 1.3 mgd. By further development of Groveland's acquifer, and developing groundwater sources in West Newbury, the safe yield can be raised to 2.4 mgd. This amount of water will allow the communities to meet estimated average day demands through the year 2020; however, estimated 1990 maximum day demands may exceed this safe yield, and additional storage facilities may be required.

i. Georgetown and Byfield--Existing safe yield of groundwater sources located in both communities is 1.8 mgd. An additional 2.2 mgd is reported able to be developed from groundwater sources. This additional amount will allow the communities to meet their estimated 2020 maximum day demands.

j. Rowley--Present source of supply is groundwater with a safe yield of 0.7 mgd. It has been reported that Rowley could develop groundwater sources with a total safe yield of 3.0 mgd. This is far in excess of the estimated 2020 maximum day demand of 1.3 mgd.

k. Merrimack--Groundwater sources are the present supply for this community. It is anticipated that future development of groundwater from the existing safe yield of 1.0 mgd to 1.6 mgd is possible, and this development will allow the community to meet its estimated 2000 maximum day demand, and 2020 average day demand.

l. Salisbury--Groundwater is the source of supply for this community which is unique in the basin because it is supplied by a private investor-owned water company. The long term safe yield of these sources is 2.2 mgd, with a maximum capacity of 3.8 mgd. The safe yield will meet estimated maximum day demands through the year 1990, and average day demands through the year 2020. The maximum capacity is sufficient to meet anticipated 2020 maximum day demands.

59. Surface Water Supply Sources:

a. Billerica--Present plant capacity is 7 mgd, however, a plant expansion to 14 mgd is now under construction. The source of water supply is the Concord River. It is anticipated that this expansion will allow the community to meet its maximum day demands in the year 2020. Although the low flow in the river could present problems in meeting future maximum day demands, it is anticipated that the State-EPA implementation schedule will augment the river's flows sufficiently to insure enough water to meet this future demand.

b. Lawrence and Methuen--Presently Lawrence supplies all of Methuen's water under a contract which expires in 1980. Both communities have undertaken engineering studies to determine the most economical way of meeting future needs. The present source of supply is the Merrimack River, and Lawrence operates a 14.0 mgd water treatment facility at the present time. A 60 percent plant expansion has been recommended by the city's consulting engineer to meet the maximum day needs of the communities past the year 1990, and the average day needs past the year 2020. The Town of Methuen's consultant has reported that Methuen could either construct its own treatment facility or continue to be served by Lawrence. The initial construction cost would be higher (estimated $898,121 annual cost versus $815,877 annual cost) than if the town continued to be served by Lawrence. However, it is estimated that as Methuen's percentage of the total treated water increased, its share of the annual cost would also increase so that by approximately the year 1990 there would be no difference in annual costs, and by the year 1993 it is estimated that it will be approximately $32,000 less expensive, on an annual cost basis for the town to have its own facility ($892,999 versus $929,228 annual cost). Also, although no figures were given, it was estimated that a further expansion of the Lawrence treatment facility would be more costly than an expansion of the Methuen treatment facility.

c. Haverhill--Present sources of supply are several surface water bodies with a total safe yield of 8.7 mgd. With the exception of a 1.0 mgd treatment plant located on Johnson's Pond, the water is untreated except for chlorination. Some alterations to existing intakes, a 12.0 mgd treatment plant, with expansion to 18.0 mgd, and development of the Little River would increase the supplies' safe yield to 18.0 mgd which would meet the estimated 2020 maximum day demands.

d. Amesbury--Present capacity of treatment facility is 3.0 mgd. Development of the Powwow River will allow the community to meet its anticipated needs through the year 2020.

60. Communities with both Groundwater and Surface Water Supplies:

a. Concord--Present sources are surface (Nagog Pond) and groundwater supplies totaling 5.5 mgd safe yield. It is anticipated that future groundwater development will increase the safe yield to 6.3 mgd, which will allow the community to meet its estimated maximum day demand through the year 1990 and its estimated average day demand through the year 2020.

b. Newburyport and Old Town--Present safe yield of the ground and surface supplies of Newburyport is 3.3 mgd. Old Town has no existing water supply source and is serviced entirely by Newburyport. Raising the Artichoke Reservoir (for which most of the land has been purchased), further developing groundwater sources within Newburyport, and development of groundwater within Old Town will increase the total safe yield to 6.8 mgd. This increase will allow the communities to meet estimated 1990 maximum day demands, and 2020 average day demands.

61. Communities Forming Small "Regional" Systems:

a. Lowell--Present capacity of treatment plant is 10.5 mgd, source is the Merrimack River; at the present time, the maximum day demands exceed the capacity; the plant has been proposed to be expanded to 30.0 mgd and service all or some of the following communities: Dracut - of which approximately the eastern third of the town is now served; Chelmsford - which has expressed the desire to purchase water from Lowell already; Tyngsborough - which presently does not have a municipal system; and Tewksbury - which requires water in the near future either from Lowell or Andover. If it is assumed that Tewksbury is serviced by Andover, because Andover has just completed its plant and is closer to Tewksbury than Lowell, then the planned expansion of the Lowell water treatment facility will be adequate to meet its needs and those of the surrounding communities through the year 2020 average day demand.

b. Andover, North Andover and Tewksbury--Andover has just completed a 12.0 mgd water treatment facility which can easily be doubled to 24.0 mgd. An intermediate step to 18.0 mgd, coupled with the existing safe yields of the other two communities, will meet estimated future needs except maximum day demands in 2020.

62. Construction cost estimates were made for all components of the "No Action" plan and are shown in Table E-4. These costs were updated to July 1975 price levels to be compatible with Regional and Sub-Regional cost estimates. Because the projects' starts would actually be staggered over the next 15 years, the following procedure was used for each project to allow aggregation of the Local Option annual costs and subsequent comparison to the Regional and Sub-Regional alternatives:

a. Determine the total investment required by the project (Sum the construction costs, contingencies, engineering and design, supervision and administration, and interest lost during construction (if construction time is greater than one year)).

b. Amortize investment (a) over 30 years at 6-1/8 percent.

c. Because project life is 50 years, and bond life is 30 years, determine the present worth of the 50 years series of annual payments for power, operation and maintenance costs.

d. Amortize (c) over 30 years at 6-1/8 percent.

e. Determine annual costs incurred to pay for major replacement of pumps, etc. in 25 years.

f. Present worth the annual major replacement costs (e) over 50 years at 6-1/8 percent.

g. Amortize (f) over 30 years at 6-1/8 percent.

h. Sum the amortized annual costs (b) + (d) + (g).

i. If applicable, i.e., project starts in a year other than 1975, discount (h) to 1975.

j. Amortize (h) if project starts in 1975, or (i) if project starts at a later date over 50 years at 6-1/8 percent to be comparable to the Federal costs.

k. Sum the amortized costs (j) for each project for comparison to the Regional and Sub-Regional Alternatives.

Table E-4

Cost Estimates for the "No Action" Alternative

Town	Existing Safe Yield (mgd)	Expanded Safe Yield (mgd)	Construction Cost ($ x 10^{6})	Average Day Demands 1990	Average Day Demands 2000	Average Day Demands 2020	Maximum Day Demands 1990	Maximum Day Demands 2000	Maximum Day Demands 2020
Communities Supplied by Groundwater									
Pepperell	1.7	3.8	0.750*	2.2	2.8	4.5	3.8	4.7	7.2
Dunstable				0.4	0.9	2.2	0.9	1.7	3.8
Westford	4.8	6.6	0.505	3.0	3.4	4.0	4.9	5.5	6.4
Littleton	1.8	3.2	0.60*	1.8	2.4	3.8	3.2	4.1	6.1
Acton	2.75	4.9	0.63	2.8	3.6	5.5	4.7	5.9	8.6
Bedford	3.30	MDC (6±)	1.59	3.0	3.2	3.4	5.0	5.4	5.6
Carlisle				1.3	1.7	2.7	2.3	3.0	4.5
Boxford				0.7	0.9	1.2	1.4	1.7	2.3
Groveland & West Newbury	1.3	2.4	1.47	1.7	2.0	2.5	3.2	3.7	4.4
Georgetown & Byfield	1.8	4.0	0.72	1.2	1.5	2.2	2.4	2.9	4.0
Rowley	0.7	1.3	0.38	0.4	0.5	0.6	0.8	0.9	1.3
Communities Supplied by Surface Water									
Billerica	14.0			5.6	6.2	7.3	8.7	9.6	11.0
Lawrence & Methuen	14.0	22.4	6.55	13.9	15.5	17.7	21.1	23.2	26.0
Haverhill	8.75	18.0	14.8	9.7	10.7	12.6	14.2	15.5	17.9
Amesbury	3.0	5.7	3.46	1.8	2.1	2.6	3.2	3.7	4.4

* Costs are estimates based upon number of wells required to deliver 1990 maximum day demands which the Towns feel capable of meeting. (Corps of Engineers review did not indicate presence of groundwater in amounts anticipated by the Towns.)

Table E-4 (Cont'd)

Town	Existing Safe Yield (mgd)	Expanded Safe Yield (mgd)	Construction Cost ($ x 10^6)	Average Day Demands 1990	Average Day Demands 2000	Average Day Demands 2020	Maximum Day Demands 1990	Maximum Day Demands 2000	Maximum Day Demands 2020
Communities Served by Both Groundwater and Surface Water									
Concord	5.5	6.3	0.38	3.4	4.3	6.4	5.5	6.9	9.8
Newburyport & Old Town	3.35	6.8	3.57	3.7	4.3	5.9	6.2	7.2	9.3
Communities Forming Small "Regional" Systems									
Lowell, Dracut, Chelmsford, & Tyngsborough	19.0	38.5	8.72	22.4	25.0	30.2	33.6	34.3	44.4
Andover, North Andover & Tewksbury	20.8	26.8	0.908	14.9	17.4	21.3	23.5	26.7	32.2

Total Construction Cost	45,283,000
Contingencies	9,056,600
Engineering & Design	7,911,000
Supervision & Administration	5,357,000
Sub-Total, Construction Cost	$67,607,600
Interest during Construction	638,000
Total Investment	$68,245,600

Annual Charges	
Interest and Amortization	3,495,000
Operation and Maintenance	1,363,100
Major Replacement	108,000
Power	492,200
Total Annual Charges	$5,458,300

SELECTING A PLAN FOR THE SHORT TERM

PRINCIPLES AND STANDARDS

63. The selection of a plan for the short term is based primarily upon the guidelines established by the Water Resources Council's Principles and Standards for Planning Water and Related Land Resources. These guidelines, through the associated System of Accounts, allow evaluation of all impacts--whether beneficial, adverse or neutral--associated with each alternative. Impacts are quantified and translated into dollar values where possible. In areas where impacts are not quantifiable, the effects of each alternative are discussed so that the reader will be aware of all the ramifications of implementing the projects. Every effort has been made to consider all significant effects of the alternatives, for even the more subtle changes to a stabilized community can have important and long lasting implications. Impacts directly from constructing the project were based on engineering plans and site maps. To relate construction activities to impact categories, estimates were made of labor demands and capital expenditures as well as the physical alterations to specific sites relating to human activity.

64. The guidelines were established under the premise that the over-all purpose of water and land re-planning is to reflect society's preference for attainment of the four objectives defined as:

a. To Enhance the National Economic Development by increasing the value of the nation's output of goods and services and improving the national economic efficiency.

b. To Enhance Environmental Quality by the management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural and cultural resources and ecological systems.

c. To Enhance Regional Development through increases in a region's income; increases in employment; distribution of population within and among regions; improvements in the region's economic base, and educational, cultural, and recreational opportunities and enhancement of its environment and other specified components of regional development.

d. To Enhance Social Well Being through increases in real income; security of life, health and safety; increasing the educational, cultural and recreational opportunities; establishing emergency preparedness and other factors contributing to the social well being.

65. A complete accounting of relevant beneficial and adverse effects of each alternative are presented in Table E-7 as they relate to the above social objectives.

66. Beneficial and adverse effects are measured in monetary terms for the national economic development objective and the regional income component of the regional development objective and for some social factors. Other beneficial or adverse effects are measures in non-monetary terms for components of the environmental quality, for the non-income components of the regional development objective, and for most social factors. Estimating these beneficial and adverse effects is undertaken in order to measure net changes with respect to particular objectives that are generated by the project. The beneficial and adverse effects on social factors are also displayed in the system of accounts.

67. Thus, there are beneficial and adverse effects for national economic development, environmental quality, regional development and social well-being objectives. These are measured in quantitative units or qualitative terms appropriate to a particular effect. The multi-objectives are not mutually exclusive with respect to beneficial or adverse effects, and decisions relating to the selection of the recommended plan are predicted on the differences in the effects of the alternative plans.

ECONOMIC ANALYSIS PARAMETERS

68. The Interest Rate--supplied by the United States Office of Management and Budget--reflects the average price being paid for money by the government. The same rate is also used for discounting purposes. The present rate is 6-1/8 percent.

69. The project life--for all alternatives--was estimated to be 50 years. This does not mean that the projects, under any alternative, would meet the water demand needs of the area for 50 years, but that the components constructed would have a usable life of 50 years.

70. The economic (bond) life for Federal bonds is 50 years; for municipal bonds, 30 years has been established as the appropriate term to maturity; therefore, these economic lives were used in the preparation of this report.

71. The price level established for this study was based upon July 1975 prices. The Engineering News Record Construction Cost Index (ENRCCI) was 2247 for this study. No changes in this price level were considered during the construction life of the project. This assumption, although not supported by historical record, should not lead to any erroneous conclusions because, in general, the rate of price level increases in the past has tended to be uniform among the various levels of the economy. There is no reason to suspect that the rate of price level change in the planning area or the New England region would vary significantly from the national average.

72. The base year established for this report is 1975. The ramifications of this base year selection are of an economic nature. All projects, of any alternative, which would be completed at a future date, would have the project costs discounted back to 1975. This means that all alternatives would be economically comparable, and allows calculation of a Benefit/Cost Ratio in the traditional manner. By having a base year, however, another assumption is made; i.e., funds for future projects would be held in escrow from the base year to the time of the project. This, in effect, reduces the annual costs for all future projects. An example will help clarify this assumption. The Regional System alternative is estimated to cost $95,385,000 to construct, this figure includes contingencies, engineering and design, supervision and administration, and interest during construction. The total annual interest and amortization charges for this construction cost would be $6,157,100 (6-1/8 percent interest over 50 years). In order to "bring back" this annual series of 50 payments, these payments must be totaled by finding the present worth of that series, then present worth that total back to the base year. This amount of money is the capital which must be borrowed now, placed in a bank to receive 6-1/8 percent interest, so that, at the end of construction of the project, the total estimated cost will be available. This money is then annualized at 6-1/8 percent over 50 years from the base year. The following calculations are performed:

a. Total construction cost = $95,385,000

b. Interest and Amortization: 95,385,000 x 0.06455 = 6,157,100

c. Interest and Amortization, present worthed: 6,157,100 x 15.49091 = $95,379,100

d. Present worth of the series, brought back to 1975: 95,379,100 x 0.58565 = $55,858,800

e. 1975 Total, amortized over 50 years: 55,858,800 x 0.06455 $3,605,700

f. b above is more than e above, therefore projects in the future appear to cost less than projects required immediately.

IMPACT CATEGORIES

73. The following impact categories encompassing those required by Section 122 of Public Law 91-611, formed a basis for determining possible effects which implementation of the alternatives may cause:

a. Noise--All three structural alternatives will cause increased levels of noise in and around the construction area itself and on roads used for hauling purposes by large trucks to and from the construction areas. The levels of noise and its associated nuisance factor will vary with the type of construction: i.e., well drilling versus earth moving or trenching, and proximity of the construction activities to residential areas. After the construction is completed, however, no noticeable increase in the level of noise is anticipated.

b. Population--The population projections used for all alternatives were furnished by the Commonwealth of Massachusetts. These projections are essentially a modified OBERS Series D. OBERS projections assume that all natural resources required for growth are present; that the unemployment rate will reflect reasonably full employment; that the cohort fertility rate for this series is 2.4, and that growth in output can be achieved without ecological disaster or serious deterioration. Thus, the projections essentially reflect historical trends: i.e., no natural resource will be a limiting factor to continued growth. Implicit in these assumptions is the fact that increased population in an area, whether that be a region or a community, will cause an increase in the density of that area because the amount of land is fixed. The anticipated populations are shown under the Regional Development section of Table E-7.

c. Displacement of People--As suggested under previous headings, certain community disruptions must be anticipated under the implementation of any construction alternative. Traffic patterns would be disrupted during the laying of pipelines in secondary roads. Neighborhoods would be altered, especially in Lawrence, by water treatment plant construction or expansions. These disruptions then would have both immediate and long lasting effects.

d. Aesthetic Values--Providing an adequate water supply, whether for a stable or dynamic population growth, will allow for an aesthetically pleasing community because lawns can be cared for; public commons, gardens and fountains can be watered; and, public wading and swimming pools can be created or operated. The open space provided by the creation of reservoirs or groundwater protection, required by the Local Option alternative is also considered to be aesthetically pleasing.

e. Housing--There should be no appreciable increase in the demand for new or rental housing under the implementation of any alternative, because it can be safely assumed that a local contractor, or one within commuting distance would be awarded the construction project (s). Therefore, housing effects of this project are considered insignificant.

f. Leisure Opportunities--Passive recreational opportunities would be provided by the Local Option alternatives due to the preservation of open space required by protection of the groundwater development areas. Active and passive recreational opportunities could be provided by all of the structural alternatives due to adequate water supply for public gardens, commons, and wading and swimming pools. The Regional and Sub-Regional alternatives could eliminate some passive recreational potential along the banks of the Merrimack River in Tyngsborough at the proposed water treatment plant site.

g. Community Cohesion--Expansion of the Lawrence water treatment facility, required by the Sub-Regional alternative, and possibly required for the short term under the Local Option alternative, should Methuen continue to be served by Lawrence, would cause disruption of the neighborhood in Lawrence where the treatment plant is located. No other disturbance to community cohesion is anticipated by implementation of any alternative.

h. Community and Regional Growth--The population projections used for this report assume growth for the region and have the underlying assumption that all resources--water, labor force, transportation, power, etc.--necessary for that growth are provided. The Demand Modification alternative alone would discourage growth because no new sources of supply are provided. The structural alternatives would allow growth, but while the Regional and Sub-Regional alternatives would allow indiscriminate growth throughout the area, the Local Option alternative would allow each community to determine for itself the size and location of that growth.

i. Institutional Relationships--The Demand Modification alternative would require changes in the Building Code, either the State's or as addenda to the local codes. The Regional and Sub-Regional alternatives would require formation of a Regional authority to own, operate and maintain the facilities proposed under these alternatives. Such a regional authority would require Legislative approval and agreement among all of the various communities. Although some communities would be required to join together under the Local Option alternative, there does not appear to be any compelling reasons for those communities which can meet their short term needs to join a regional system.

j. Health--The Demand Modification alternative should have no effect on the health of the region. The water quality under the Local Option alternative will vary among communities; however, the new Drinking Water Standards, should limit the quality variations to relative degrees of hardness and softness. Under the Regional or Sub-Regional alternatives, the water quality throughout the area would be of uniformly high quality.

k. Municipal Tax Revenues--All structural alternatives have both beneficial and adverse effects upon the municipalities' financial structure. The beneficial impacts, for instance, include expansion or location of wet industries, which would increase the tax base by providing more employment opportunities. The most notable adverse impact would be either an increase in water rates/taxes to repay the initial capital outlay, or in tax revenues lost due to removal of lands from private to public ownership due to construction/expansion of treatment facilities and reservoir construction. However, the amount of land, on an areal basis, which would be removed from the tax is insignificant.

l. Property Values--A potable water supply of sufficient quantity will allow the maintenance of existing property values by providing an adequate water supply for municipal and industrial needs including the water necessary for landscaping purposes. In areas where there is a lack of supply--water use bans are enforced in the summer, for instance--the increased quantity will improve property values by reducing the number of brown lawns thereby adding to the overall pleasing appearance of the community.

m. Land Use--The Regional alternative would change the land use patterns of approximately 100 acres in Tyngsborough and approximately five one-half acre plots throughout the planning area for pumping stations. The Sub-Regional alternative would have one more pumping station than the Regional, and would also change 1-1/2 acres in Lawrence at the water treatment plant. The Local Option alternative would change approximately 590 acres in the communities listed in Table E-5, due to public health requirements for protection of the proposed groundwater resources.

TABLE E-5

GROUNDWATER DEVELOPMENT LAND REQUIREMENTS

Community	Acreage	Percent of Town Land
1. Pepperell	60 acres	0.4
2. Westford	45 acres	0.2
3. Littleton	45 acres	0.4
4. Acton	60 acres	0.5
5. Concord	35 acres	0.2
6. Groveland	10 acres	0.2
7. West Newbury	95 acres	1.0
8. Georgetown	180 acres	2.1
9. Rowley	35 acres	0.3
10. Merrimack	25 acres	0.4
Total	590 acres	0.5

In addition, reservoir development in Amesbury would change approximately 212 acres, and the Little River diversion in Haverhill would change approximately 52 acres of existing land use patterns. Increasing the height of the Upper Artichoke Reservoir will inundate an additional 60 acres of land in Newburyport and West Newbury. These land use pattern changes are discussed more fully under the applicable categories in the following paragraphs and are shown on Table E-7 at the end of this section of the report.

n. Public Facilities--The report's topic is the expansion of a particular public facility to meet the anticipated increased demands of the region. Other than the disruptions commonly associated with urban construction--traffic pattern disruptions, accidental water main breakage, etc.--no long term disruptions are anticipated. Lowell has reported a hospital expansion delay because of the lack of sufficient quantity of potable water. The timely implementation of a structural alternative would allow the expansion of the necessary public facility.

o. Public Services--Increased public services, with respect to increased quantity of water, would be attained by implementation of any of the structural measures.

p. Employment/Labor Force--The Lowell, Lawrence, Haverhill area is one of relatively high unemployment. The City of Lowell has estimated that approximately 6900 jobs have been constrained due to the lack of potable water. This water shortage has reportedly delayed completion of an industrial park, and prohibited expansion of industrial, commercial, and service-oriented businesses. Provision of this water, through a structural alternative, would alleviate this unemployment rate. In addition large construction efforts, such as the Regional and Sub-Regional alternatives, would have a large, short term, economic boost; however, the project could not begin construction until the early 1980's, and there is no way to determine the employment characteristics of the region into so distant a future. Therefore, estimates of the possible economic impetus of such projects is ameliorated by the lead time before construction would actually take place.

q. Business and Industrial Activity--As previously indicated, all projections assume adequate natural resources to allow growth. Growth, as meant here, is not merely population but also economic. For this area to grow, it must rely upon industrial growth. Therefore, if a community or area desires growth, then all of the required resources--power, transportation, water, land availability, labor force, etc.-- must be provided. Thus, water is a requirement for economic stability. Its relative degree of importance, however, will depend upon factors such as availability, adequacy of supply, and quality. Effects on commercial activity would be of a secondary nature. That is, approximately

2.3 service type jobs are required for every 1 manufacturing job. Therefore, after construction, the projects would allow normal expansion to occur. During construction, increases in commercial activity, especially lumber and construction materials, would be felt. Eating establishments would also notice increases during construction, however in both cases the intensity of the increase would vary with the type and amount of construction activity.

r. Man-Made Resources--Implementation of the Regional or Sub-Regional alternatives would use far more power than the Local Option alternative. This is a use of a man-made resource, and is indicated on Table E-7 as an external diseconomy to these alternatives. By the protection of the groundwater development areas, passive recreational areas are created with the implementation of the Local Option alternative. All of the structural alternatives would allow maintenance or creation of public recreational areas. The two reservoirs proposed under the Local Options alternative would create water bodies which could enhance the surrounding areas and increase property values.

s. Natural Resources--The obvious natural resource which will be used, under any structural plan, is water itself. The most efficient use of this resource would, however, require institution of the Demand Modification alternative. This would eliminate the "waste" of water of which one is unaware, for example, the 20 gpm shower head when 3 gpm will suffice and use of a water using instead of water saving toilets. Fish life within the Merrimack River does not appear to be significantly affected by implementation of any of the structural alternatives, however, the Local Option alternative may impact upon the aquatic biota within the tributaries due to the extensive reliance upon groundwater flows.

t. Air Pollution--The Demand Modification alternative would have no effect upon ambient air quality during construction due to vehicle exhaust, earth moving, trenching, blasting (if required) and other construction related activities. This is seen as a short term, site specific nuisance which is an unavoidable part of any construction project. In some instances--dampening dirt construction roadways to keep down dust, for example--actions can be taken to reduce the anticipated problems. No significant air pollution problems are anticipated either during construction, or after implementation of any of the structural alternatives.

u. Water Pollution--Water treatment plant sludges, if discharged directly to the watercourse, tend to deposit in the stream, forming noxious sludge banks. (Because of the chemical addition to produce settling during treatment, and the increased solids concentration which the settling process produces, the agglomorated solids are much more apt to settle out in the receiving stream after treatment than before). The two treatment processes generally preferred are lagooning with effluent discharged to the river or direct discharge to a waste treatment facility. Lagooning requires large land areas, and, with alum sludges, has enjoyed limited success because of the gelatinous nature of the sludges. The decision to lagoon would be site specific, depending upon land availability, nature of the sludge to be treated and if the effluent would meet State EPA water quality standards. Discharge to a sanitary sewer for treatment at a wastewater treatment facility presumes that the collection and treatment systems have sufficient capacity to accommodate this extra waste load. It is uncommon for existing wastewater plants to have this capacity but proposed plants can have this feature designed in. If the groundwater that is developed proves excessively hard and is treated, disposal of this sludge would require the same general considerations as the water treatment plant sludges, with the added hindrance that wells or well fields are generally remote from sanitary sewers, however, the loads are generally much smaller.

v. Displacement of Farms--The Regional and Sub-Regional alternatives would remove approximately 60 acres of land from corn production in the Town of Tyngsborough. This is the only area identified as having intensive agricultural activity within the region's total of 27,000 acres of total available cropland. Therefore, no significant effect is anticipated by the implementation of any structural plan.

w. Groundwater Regime Alteration--Implementation of the Regional or Sub-Regional alternative would maintain the status quo with respect to groundwater regimes. The Local Option alternative would further develop groundwater sources with the attendant alterations in groundwater flow patterns. These alterations are not expected to be significant in themselves, but may have a more noticeable secondary effect discussed below.

x. Surface Flow Effects--Groundwater development, required under the Local Option alternative, may have noticeable impacts on the low flows in the Merrimack River tributaries. This effect would be to lower tributary flows during the summer months. The impact which such lowering will have will be tributary specific, i.e., the hydro-geologic relationships governing the stream flow are different for each stream. Such a determination is beyond the scope of this study, but should be investigated during the actual development of the groundwater sources. The Billerica water treatment facility, which utilizes the Concord River as a source of supply, will have the ability to remove 14 mgd after its present expansion program. With the flow augmentation which is anticipated after construction of the upper basin wastewater treatment facilities, this amount of water is not expected to adversely impact on the river. The effects of any of the structural alternatives upon the Merrimack River itself are considered to be insignificant when the entire river is considered. Consumptive losses would amount to approximately 30 cfs, which is not a significant amount when compared to the flow in the river. The dams and canals in Lowell and Lawrence operate above 3500 cfs, that is, if the canals are not in use (for example, on weekends), and the flow in the river is less than 3500 cfs (for example, in the summer), water ponds behind the dams. Any diversion during this time would aggravate an existing environmentally poor condition.

EVALUATION OF ALTERNATIVES

74. The System of Accounts requires evaluation of all the alternatives against the general impact categories given above, within the framework of the four objectives established for water and related land resource uses--National Economic Development; Environmental Quality; Regional Development; and Social Well Being. Table E-7, given at the end of this section of the Report, lists the four major alternatives and the major impacts surfaced. It is a summation of the discussion which follows.

75. National Economic Development (NED) Account: An attempt to quantify each alternative's effect upon the value of the nation's output of goods and services and the effect upon the national economic efficiency. This is most often illustrated by the computation of a Benefit/Cost Ratio. The B/C ratio is simply the sum of all the annualized anticipated costs of the alternative. If this ratio is greater than one (benefits are greater than costs) the alternative may be economically justified. The System of Accounts attempts to insure that all costs, and all benefits are assessed so that the B/C ratio reflects the most accurate economic picture available.

76. The calculation of benefits involves evaluating the increased output of goods and services; the value of output resulting from external economies; and the value of output resulting from the use of unemployed or underemployed segments of the labor force. In the traditional method for water supply calculation of the value of increased output of goods and services, the value used is the cost of the project's most likely alternative. For water supply, this value is assumed to be the cost of water. In this report, the most likely alternative to either the Regional or Sub-Regional systems would be the Local Option Plan.

77. Because there is no true alternative to the non-structural plan--Demand Modification--the value used was the summed, annualized savings in the operation, maintenance and power costs which would be realized by not utilizing the full capacity of the treatment plants and pumping stations; and the savings accrued by delaying capital expenditure for the expansion of existing facilities. An example is in order. The Regional System has a treatment facility designed to accommodate 47 mgd of water. The Demand Modification technique would decrease demands approximately 9 percent, or 4 mgd, thus there would be a savings in the operation and maintenance costs because less flow means less power and chemical usage. This savings would be accrued over however long it would take for the demand to equal the design plant capacity. This number of years is also a savings in the capital outlay required for expansion because of the effect of present worthing the capital costs. The savings from each alternative resulting from the implementation of the Demand Modification techniques would be compared to the estimated costs for its implementation to calculate the B/C ratio. Thus, this calculation differs from the traditional methodology which was utilized for the other alternatives.

78. The use of reduced capital cost as benefits, that is, the savings which would be realized by constructing a smaller plant in anticipation of the implementation of the Demand Modification techniques, was considered but rejected for two reasons. The first is that the Demand Modification reduction estimates are based upon studies and not upon experience. The closest area which has inaugurated such a program, that administered by the Washington Suburban Sanitary Commission, has estimated demand reduction at between 5 and 6 percent. However, not sufficient time has elapsed to allow a complete and accurate assessment of the program. Some areas have shown a decreased demand while under study, say six months, and after the supposed conclusion of the study, the demand has risen rapidly to nearly the pre-study levels. Thus, there is some uncertainty as to whether the people would really try to conserve water, and how much percentage reduction would be accomplished.

The second reason is that if a B/C ratio greater than unity would be obtained by comparison with power, operation and maintenance costs and capital expenditure savings only, then the B/C ratio would certainly be greater than unity for capital cost savings. Thus, it would be a conservative estimate and would also provide a sensitivity analysis on the implementation of this program.

79. The beneficial value of output resulting from external economies is almost non-quantifiable because of the inherent difficulty in trying to correlate cause and effect. An external economy, or secondary benefit, exists when industry or employment in one area allows the development or expansion of industry or employment in another area. These areas may be contiguous or quite far apart. Increased employment in one area, for whatever the reason, causes that area to purchase more goods and services. This causes an increase in the production of these goods, and in such ancillary items such as retailing and transportation. The obvious problem here is differentiating the causes of the increase in industry or employment. Was the increase in production of appliances, in, say Ohio, due to the construction of a large hydroelectric power station on the eastern seaboard, or increased aircraft production on the west coast? To further complicate matters, it cannot easily be determined if an industrial expansion in one area was due to the availability of transportation, labor, energy, water, land or one of the other items necessary for industrial development or expansion. Therefore, while it is recognized that secondary benefits are generated by increases in industry or employment, no monetary figure is claimed by any of the alternatives presented here because of the extreme difficulty in assessing the actual dollar amount.

80. The value of output resulting from the use of unemployed or underemployed is calculated in the following manner. Experience has shown that 27 percent of the direct construction cost (engineering and design, supervision and administration, real estate, etc., are not included) is the cost of labor, and that up to 75 percent of that labor force will be hired locally. Due to the high unemployment rate in the planning area, it has been assumed that the entire local labor force will be from the ranks of the underemployed and unemployed. This amount of money is evenly divided over the life of the project to obtain an average annual figure. This series is present worthed to the beginning of construction; this figure is present worthed to the base year (1975) and then amortized over 50 years (the project life) at 6-1/8 percent (the interest and discount rate). This economic adjustment is required to insure homogenity of all benefits and costs.

81. Due to the ever increasing area which the System of Accounts requires analysis of, an additional benefit may be calculated from the Engineering and Design and the Supervision and Administration costs. For the Local Options alternative, half the Engineering and Design costs were assumed to be occurring in the larger area affected by the plan, and the other half within the rest of the nation. The total figure was used because of the less than full employment experienced in the rest of the country. The Engineering and Design and Supervision and Administration costs for the Regional and Sub-Regional Plans were assumed to be benefits to the rest of the nation because these functions would be performed by the Corps of Engineers if these projects were constructed. Supervision and Administration costs for the Local Options alternative were not considered benefits, because these are duties commonly performed by the communities Engineering or Public Works Departments, and few projects are large enough to warrant recruitment of help for these projects.

82. Under the NED account, the calculation of costs is based upon the annualized first costs of the project and any identifiable external diseconomies. The only external diseconomy which could be surfaced was the additional power cost which the Local Options alternative requires due to the rather large dependence upon groundwater. This is illustrated on the Table as the difference between power expenditures for the different alternatives. It is considered to be an external diseconomy because it is a consumption of a vital resource which is unique to that alternative, i.e., the Local Options alternative consumes more power than either of the other alternatives, and by the dollar amount shown. The first costs for the Regional and Sub-Regional System were annualized, present-worthed, discounted to 1975 and annualized. Each of the projects required for the Local Options alternative was assumed to be constructed at the date when water would be required, and these costs were annualized, present worthed, discounted to 1975 if required, and annualized. Again, this economic adjustment was to insure homogenuity of all benefits and costs.

83. The Environmental Quality (EQ) Account is an attempt to quantify the impacts which each alternative will have upon the environment. Where impacts cannot be quantified, then assessment is qualitative, so that at least the ramifications will be shown. The following areas were selected from the impact categories described earlier and describe possible environmental impacts associated with the various alternatives:

a. Land Use--The Demand Modification Alternative would not have an appreciable effect upon the area's land use because it is non-structural. However, use of water saving appliances may allow development in areas presently constrained by septic tank limitations.

The Local Option Alternative will inundate approximately 26 acres of land in Haverhill presently zoned for conservation; and a like number of acres in the same community will be removed from an area zoned for an industrial park. This acreage is required to develop the Little River for water supply. Within Amesbury approximately 212 acres of land will be inundated for development of the Powwow River to serve that community's future water supply needs. The Upper Artichoke Reservoir in West Newbury and Newburyport requires raising if it is to continue to meet the water needs of Newburyport. This will remove about 60 acres of land from its present status.

The development of well fields will also require land taking to preserve more open space as a buffer for health purposes in those communities relying upon groundwater for a supply source. Approximately 590 acres of land are required for protection of proposed groundwater sources under the Local Options alternative in 10 communities within the planning area. This amount of land represents 0.5 percent of aggregated communities' land, however, the individual percentages range from a low of 0.2 percent in Concord to a high of 2.1 percent in Georgetown. All communities affected and the amount of land in question are listed in Table E-5. This amount of land can add to the open space of each community and give a "greenbelt" effect to certain areas. It will also preclude development pressures in those areas.

On the other hand the Regional and Sub-Regional alternatives will remove approximately 100 acres of land from farming/passive recreational usage along the banks of the Merrimack River in Tyngsborough. In addition, the Sub-Regional plan would change approximately 1.5 acres of presently residential land in Lawrence to government owned land for the water treatment plant expansion. Under both the Regional and Sub-Regional Systems, scattered parcels of land would be required throughout the region for pumping station locations. These parcels would be small (approximately one-half acre each) in comparison to the area of the community, or even to the area required by the water treatment plants.

b. Surface Flow Effects -- The flows in the Merrimack River would be essentially unchanged, under any alternative, when the entire river is considered. This is due to the fact that approximately 80 percent of water withdrawn for water supply would be returned through the wastewater treatment plants' discharge pipes. Under the Regional or Sub-Regional alternative, approximately 140 cfs, in total, would be withdrawn from the river on the average for water supply purposes. Of this amount, only about 30 cfs would not be returned to the river due to consumptive losses. (The average low flow in the river during the lowest flow month is 2200 cfs). A report* on the Merrimack's estuary indicated that withdrawals of 100 cfs would produce no significant ecological effects during any month of the year. Therefore, a loss of 30 cfs would be assumed to produce no significant impacts. A second report ** on the possible effects of diversions on the anadromous fish restoration program, concluded that in-basin water supply requirements represented an insignificant drain upon the river's resources, even in the year 2020. It can, therefore, be assumed that the short term demands, being less than the long term demands, would have an even smaller impact. The only areas of concern are at the withdrawal points themselves. At these points, the intakes should be designed to minimize the rheotaxis effect on migrating fish, and to attempt to shunt floating biota away. These should be the only areas of concern as far as using the river for water supply is concerned.

84. An increase in the usage of groundwater and the tributaries themselves for water supply purposes, as advocated in the Local Options alternative, could cause a reduction in tributary flows during the normally low flow periods of the year. This reduction could affect the tributaries' ecosystems, however, it is beyond the scope of this report to do more than flag the possibilities of such an impact. Because the Regional and Sub-Regional alternatives do not use the tributaries, there would be no further reduction in their flows; therefore, the ecosystems should preserve the status quo providing no other external forces (such as increased/decreased pollutional loads) are applied.

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* Ecological Study Merrimack River Estuary - Massachusetts, prepared for the New England Division, Corps of Engineers by Normandeau Associates, Inc., 1971.

** An Investigation of Some Environmental Impacts for Possible Diversion of Flow from the Merrimack River, prepared for the New England Division, Corps of Engineers by Jason M. Cortell and Assoc., April, 1975.

85. The Regional Development (RD) Account is an attempt to quantify all impacts which the alternatives will have upon the planning area. Where practical, actual numbers are used, where quantification is impractical or impossible, then a qualitative assessment has been made. The following impact categories were investigated for each alternative's effect upon Regional Development:

a. Population--The population figures used were provided by the Commonwealth of Massachusetts for each community. (Some modifications were made at the Regional Planning Agency level for individual towns, however, the RPA totals were adhered to). These figures have assumed growth with a cohort fertility rate of approximately 2.4, and have also assumed all necessary resources will be available to allow this growth to occur. The Demand Modification alternative should not influence growth or growth patterns in any manner. The Regional and Sub-Regional alternatives will provide the water necessary for growth, but will allow it to occur anywhere within the planning area. This could put increased pressure upon those communities which do not want growth, or wish to restrict it to certain areas. The Local Options alternative will give the communities more of a sense of independence than the other two structural alternatives, by allowing the communities to promote, retard or channel growth as they see fit.

b. Land Use--The effects of each of the structural alternatives on land usage are listed below. The only effect which Demand Modification may have on land usage might be to allow development on land now considered marginal for subsurface sewage disposal systems.

1. Regional Alternative - If all the land required for the Tyngsborough treatment facility and its future expansion was purchased at one time, 0.9 percent of Tyngsborough's land area would be changed from its present usage. Access to the site would be improved from its present condition, however, the treatment plant area would be removed from passive recreational usage. In this parcel, approximately 5 acres of land abutting the river has been subdivided into 20 parcels of land for seasonal usage. Eleven cottages have been erected for this purpose. Under this alternative, the land and cottages would be purchased to allow for future expansion. Real Estate acquisition and relocation assistance costs have been estimated and are included in the cost summary, Table E-7.

2. The Sub-Regional Alternative - In addition to the Tyngsborough site, this would also necessitate the purchase of 1.5 acres of land improved with 1-single family, 2-two family and 5-three family residences in the City of Lawrence near the existing water treatment facility. Both the Regional and Sub-Regional alternatives would also require approxi-

mately 6 half acre plots for pumping stations, scattered throughout the region. These pumping stations should not take any existing houses, nor significantly impact on the area where they are erected.

3. Local Option Alternative - This alternative requires the most change in land use patterns throughout the region. Over 900 acres of land will be removed from possible development. However, this 900 acres represents less than three-tenths of one percent of the regions total acreage of 362,000 acres. From a regional perspective, therefore, this is considered an insignificant amount. The site specific effect of reservoir development and space preservation around groundwater developments could be extremely significant to the individual communities. Developmental pressures around these areas may be great, and may occur in an area which the community, for any of a number of reasons, may not wish to experience a rapid growth. Development of the Powwow River in Amesbury would not have an effect upon houses or the road networks if spring floods were pumped to an offstream storage reservoir south of Friend Street. Two or three houses will be affected by the planned expansion of the Upper Artichoke Reservoir in West Newbury and Newburyport. Approximately 26 acres of conservation land will be inundated in Haverhill by development of the Little River. A like number of acres of land zoned for an industrial park will also be inundated. Because this impoundment will be for water supply, special drainage would be required in the industrial park, if developed, as will a sewerage system. If Methuen continues to be supplied by the City of Lawrence, a 60 percent expansion of that plant would require the taking of one two-family house, one three-family house, an unimproved building lot, and portions of three other building lots, including two garages. If Methuen should decide to build its own treatment facility, then no houses would be taken for this construction.

c. Housing -- The Demand Modification alternative will have an insignificant monetary effect, because it is estimated that new housing construction costs would increase by approximately $23 per house if the alternative is implemented. Timely implementation of any of the structural alternatives will insure that no building bans will be initiated due to lack of water. However, there will be land and house takings if any of the structural alternatives are implemented. The Regional alternative would take 11 seasonal cottages in Tyngsborough. The Sub-Regional alternative would take a total of 20 dwelling units (1 single family, 2 two family and 5 three family residences) in the City of Lawrence. The Local Option alternative, if Methuen continues to be served by Lawrence, would take a total of 5 dwelling units (1-two family and 1-three family residence) in the City of Lawrence. If Methuen should decide to construct its own facility, no house would be taken. By the construction of reservoirs, it is possible that housing development pressures may be brought in Amesbury, Newburyport and West Newbury around the reservoirs.

d. Municipal Finance--Implementation of either the Regional or Sub-Regional alternative would not significantly alter the tax base of any of the communities within the region. The Local Options alternative would remove some 32 acres of industrial park zoned land which may have an impact at a future date. Most water supply related construction activities require either raising taxes or water rates to pay for the construction. Obviously, implementation of any of the structural alternatives would necessitate such action. However, the increases would be community specific, depending upon a number of factors (such as previous indebtedness, type and amount of construction, addition of new employees, etc.) and, therefore, only total annual costs are shown for the Regional and Sub-Regional alternatives, and the annual cost per community for the Local Options alternative. No attempt was made to determine the effect or the tax on water rates of each community.

e. Business/Industrial Activity--The assured quantity and quality of water will allow economic growth, and, therefore, contribute to the economic stability of each community. Again, it must be emphasized that water supply is one of a set of natural resources which must be provided to allow growth to occur. Any of the structural alternatives, if implemented in a timely manner, would provide the necessary water for such growth. The City of Lowell has reported that approximately 6900 jobs have been held in abeyance due to the lack of water. In an area of high unemployment, such as Lowell, this number of jobs would effectively cut the unemployment rate in half. Such a significant decrease in unemployment would have two direct benefits; increase the regional economy, and decrease the dollar drain on the unemployment compensation benefits. This is reflected in Table E-7 under the Regional Development Account by showing figures for full employment (4 percent unemployed) for the years 1990 and 2020.

86. The Social Well Being (SWB) Account attempts to elicit all possible sociological effects which implementation of any of the alternatives may cause. The following categories were utilized to give a basis for surfacing any possible impacts:

a. Population--The Demand Modification alternative is not anticipated to impact on either population growth or distribution. The Regional and Sub-Regional alternative would allow growth in those communities desiring it, and would also allow channelization of such growth.

b. Land Use--The Local Option alternative would provide more of a "greenbelt" effect than the other two structural alternatives because of the development of reservoirs and development of groundwater sources. Other changes would be insignificant to the region as a whole because of the small amount of land which would change usage under the structural alternatives. The Demand Modification alternative would not have an impact upon land usage within the area. To determine if gross changes in population densities would be caused by implementation of the Local Option alternative due to surface and groundwater development, the estimated community populations were divided by the gross land area in the community with and without the proposed development. Only two differences were noted in the groundwater communities, both occurring in the year 2020, and both an increase of one-tenth of a person per acre. The communities are Acton and Georgetown, where the densities changed from 3.3 to 3.4 persons per acre and 1.4 to 1.5 persons per acre respectively. Amesbury, with development of the Powwow River, has an increase from 1.9 to 2.0 persons per acre in the year 1990, and 2.2 to 2.3 persons per acre in the year 2020. Haverhill shows no change. Data for all communities are given in Table E-6.

c. Housing--Because of the use of smaller tank toilets and restricted flow shower nozzles required in new housing under the Demand Modification alternative, a change in life style is required. For example, some of the reduced flow shower nozzles make a small sound when in use; this has, reportedly, bothered some users enough to replace the shower head. The structural alternatives would allow housing to be built; however, their implementation by themselves is not considered to increase such construction, or impact on rentals during construction.

d. Education--The timely provision of adequate water supply through implementation of one of the structural alternatives will remove one possible restriction to the expansion or construction of the physical plants of education. This secondary effect is the only one which is anticipated if a structural alternative is implemented. The Demand Modification alternative, which is a conservation measure, should be explained and encouraged in the schools along with other conservation practices. This would have the greatest educational impact of all of the alternatives.

e. Community Image--Implementation of a structural measure, to insure adequate water supply by insuring necessary community services such as fire protection and can enhance a community's image by insuring green lawns, public parks and gardens, fountains, and allowing the construction or maintenance of wading and swimming pools, for recreational usage. No effect on community image is anticipated by implementation of the Demand Modification alternative.

f. Community Disruption--Construction projects within a community of course cause disruptions to that community during construction to a greater or lesser degree depending upon type of construction, location, etc. Effects of the project can be long lasting, if, for example, a new road is built or an old one dead-ended or abandoned. The Regional and Sub-Regional alternatives would cause the most disruptions to traffic patterns throughout the region, with the Local Option alternative causing the least traffic disruptions. The Sub-Regional alternative would cause disruption of the neighborhood by taking houses and dead-ending one street in Lawrence due to treatment plant expansion; however, some of the houses will be taken in the Local Option alternative if Methuen continues to be served by Lawrence. The Regional alternative causes traffic disruption during construction, but no long term impacts are predicted. The Sub-Regional alternative, has the same short term impacts as the Regional alternative, with the added long term impact of the neighborhood disruption in Lawrence. The Local Option alternative will have relatively few traffic disturbances, but the expansion of the Lawrence water treatment facility (should it occur) and the construction of two new reservoirs and groundwater development will have a more long lasting effect upon the region than either the Regional or Sub-Regional alternative. No road networks, public buildings or facilities will be changed or altered by any of the structural alternatives. The Demand Modification alternative is not seen as causing any community disruptions.

87. The following table lists the major impacts surfaced in all categories for all of the alternatives:

TABLE E-6

Community	Acres Area	Acres Lost	1970 Pop.	1970 Density	1990 Pop.	1990 w/wo	2020 Pop.	2020 w/wo
Pepperell	14,720	60	5,795	0.4	15,200	1.0/1.0	27,300	1.9/1.9
Westford	19,974	45	10,275	0.5	34,100	1.7/1.7	35,800	1.8/1.8
Littleton	10,534	45	6,296	0.6	11,100	1.1/1.1	20,300	1.9/1.9
Acton	12,838	60	14,578	1.1	26,500	2.1/2.1	43,000	3.4/3.4
Groveland	5,997	10	5,325	0.9	11,000	1.8/1.8	13,200	2.2/2.2
West Newbury	9,382	95	2,228	0.2	3,300	0.4/0.4	4,000	0.4/0.4
Georgetown	8,384	180	5,271	0.6	7,000	0.8/0.8	12,000	1.5/1.4
Rowley	12,166	35	3,006	0.2	4,000	0.3/0.3	5,700	0.5/0.5
Merrimack	5,779	25	4,184	0.7	6,000	1.0/1.0	6,900	1.2/1.2
Concord	15,974	35	15,971	1.0	24,200	1.5/1.5	39,400	2.5/2.5
TOTAL (GW)	115,748	590	72,929	0.6	142,400	1.2/1.2	207,600	1.8/1.8
Amesbury	8,838	212	11,333	1.3	17,000	2.0/1.9	19,500	2.3/2.2
Haverhill	22,932	60	45,643	2.0	55,000	2.4/2.4	61,100	2.7/2.7
TOTAL (S)	31,770	272	56,976	1.8	72,000	2.3/2.3	80,600	2.6/2.5
GRAND TOTAL	147,518	862	129,905	0.9	214,400	1.5/1.4	288,200	2.0/2.0

Table above illustrates population densities (people per gross acre of community) for the with and without Local Option alternative implementation.

88. The evaluation of the short term alternatives displayed on the System of Accounts Table includes the labeling of the National Economic Development Plan, the Environmental Quality Plan and listing the trade-offs performed in selecting the recommended plan.

89. The NED plan is the alternative, or combination of components which addresses the planning objectives and increases the national economic efficiency. The least cost alternative, which addresses all of the short term needs, is the Local Option alternative. This alternative, therefore, is the NED plan.

90. The EQ plan is that which enhances the cultural and natural environment. The alternative which maximizes the efficient use of the region's water resources, and which can be a vehicle to teach conservation measures, is the Demand Modification alternative. Therefore, this alternative, while not meeting all the planning objectives, is the EQ plan.

91. The NED plan can be implemented in a more timely fashion than either the Regional or Sub-Regional plans. Its other positive features, when compared to the other structural alternatives, include being less economically expensive; less disruptive during the construction phase; requires no regional institutional arrangements; and, allows each community the choice of whether or not to provide for growth. The major negative effects, against which the positive must be compared, include: varying finished water quality; local economic situation (s) could prevent timely implementation of the plan, even if the community desires growth; no large construction project will take place, therefore, no significant change in employment will accrue due to the projects; possible reduction of tributary low flows due to increased groundwater pumping; and, approximately 8 times the amount of land will have its use pattern changed than in the other structural alternatives.

92. The relative significance of each of the advantages and disadvantages listed above warrants further discussion. The element of timeliness will depend upon each individual community. Therefore, it has equal weight as an advantage or disadvantage. Under the proposed EPA drinking water standards, the variation in water quality should be limited to variations in the relative hardness or softness of the different supplies. The amount of land required by the NED plan, although 8 times that required by the other structural alternatives, amounts to only about 900 acres for the total region. Because the total region encompasses about 362,000 acres, this is considered an insignificant amount. Further, the land use change will preserve open space, and therefore, would not be considered harmful by all the people of the region. The most significant effect would appear to

be the lack of a large influx of construction money at one time, rather than the small, individual sums spread out over time. If the projects in the Regional or Sub-Regional plans could begin construction within one or two years, there could be a significant impact on the area's unemployment. The earliest these projects could realistically begin construction would be around 1980, and the economic condition of the area at that time cannot be estimated with any great certainty. This vagueness tends to lessen the possible economic impact of these projects. Because the NED plan is less disruptive during the construction periods; is less expensive; allows local determination of one aspect of growth control, and does not require formation of a regional institution, the NED plan has been selected for recommendation.

93. The EQ plan has the disadvantages of being extremely difficult to implement and enforce because legislative action is required to change the present State Building Codes; however, its main disadvantage lies in the fact that a change in personal life style is required. With the dawning recognition of the finite amount of resources available, it is possible that the EQ plan could be implemented and become a vehicle for teaching other resource conservation practices. Because it provides for a more efficient use of a natural resource, and extends the physical life of the proposed facilities which will realize an economic benefit, the EQ plan is also recommended in conjunction with the NED plan.

TABLE E-7 SYSTEM OF ACCOUNTS

PLAN A — LOCAL OPTIONS — LOCATION OF IMPACTS

ACCOUNTS	Within the Immediate Planning Area		Within the Rest of the Study Area		Within a Larger Area Affected By the Plan		Within the Rest of the Nation	
I. NATIONAL ECONOMIC DEVELOPMENT	Reg.[1]	Sub.[2]	Reg.	Sub.	Reg.	Sub.	Reg.	Sub.
A. Beneficial Impacts (specify separate benefits and source.)								
1) Value of increased outputs of goods and services	7.499	7.073	7.499	7.073	7.499	7.073	7.499	7.073
2) Value of output resulting from external economies	Non-Quantifiable, however increased industrial output will, through multiplier effects, increase cash flow & taxes; lessen monetary drain for unemployment and welfare benefits; and, finally increase the G. N. P.							
3) Value of output from use of unemployed or, underemployed resources in construction or installation	0.493		0.493		0.705		0.917	
4) Total NED benefits	7.992	7.566	7.992	7.566	8.204	7.778	8.416	7.990
B. Adverse impacts (specify separate costs and source).								
1) Project costs	5.458		5.458		5.458		5.458	
2) Losses resulting from external diseconomies								
3) Total NED costs	5.458		5.458		5.458		5.458	
C. Net NED costs	-2.534	-2.108	-2.534	-2.108	-2.746	-2.320	-2.958	-2.532
D. B/C Ratio	1.46	1.39	1.46	1.39	1.50	1.43	1.54	1.46

PLAN B — REGIONAL SYSTEM — LOCATION OF IMPACTS

ACCOUNTS	Within the Immediate Planning Area	Within the Rest of the Study Area	Within a Larger Area Affected By the Plan	Within the Rest of the Nation
I. NATIONAL ECONOMIC DEVELOPMENT				
A. Beneficial Impacts (specify separate benefits and source.)				
1) Value of increased outputs of goods and services	5.458	5.458	5.458	5.458
2) Value of output resulting from external economies	Non-Quantifiable, however increased industrial output will, through multiplier effects, increase cash flow & taxes; lessen monetary drain for unemployment and welfare benefits; and, finally increase the G. N. P.			
3) Value of output from use of unemployed or, underemployed resources in construction or installation	0.490	0.490	0.490	1.071
4) Total NED benefits	5.948	5.948	5.948	6.529
B. Adverse impacts (specify separate costs and source).				
1) Project costs	7.499	7.499	7.499	7.499
2) Losses resulting from external diseconomies	0.492[3]	0.492	0.492	0.492
3) Total NED costs	7.991	7.991	7.991	7.991
C. Net NED costs	2.043	2.043	2.043	1.462
D. B/C Ratio	0.74	0.74	0.74	0.82

PLAN C — SUB-REGIONAL SYSTEM — LOCATION OF IMPACTS

ACCOUNTS	Within the Immediate Planning Area	Within the Rest of the Study Area	Within a Larger Area Affected by the Plan	Within the Rest of the Nation
I. NATIONAL ECONOMIC DEVELOPMENT				
A. Beneficial Impacts (specify separate benefits and source.)				
1) Value of increased outputs of goods and services	5.458	5.458	5.458	5.458
2) Value of output resulting from external economies	Non-Quantifiable, however increased industrial output will, through multiplier effects, increase cash flow & taxes; lessen monetary drain for unemployment and welfare benefits; and, finally increase the G. N. P.			
3) Value of output from use of unemployed or, underemployed resources in construction or installation	0.442	0.442	0.442	0.966
4) Total NED benefits	5.900	5.900	5.900	6.424
B. Adverse impacts (specify separate costs and source).				
1) Project costs	7.703	7.703	7.703	7.703
2) Losses resulting from external diseconomies	0.467[3]	0.467	0.467	0.467
3) Total NED costs	7.540	7.540	7.540	7.540
C. Net NED costs	1.640	1.640	1.640	1.116
D. B/C Ratio	0.78	0.78	0.78	0.85

PLAN D — DEMAND MODIFICATION — LOCATION OF IMPACTS

ACCOUNTS	Within the Immediate Planning Area			Within the Rest of the Study Area			Within a Larger Area Affected by the Plan			Within the Rest of the Nation		
I. NATIONAL ECONOMIC DEVELOPMENT	Local Options	Reg.	Sub. Reg.	Local Options	Reg.	Sub. Reg.	Local Options	Reg.	Sub. Reg.	Local Options	Reg.	Sub. Reg.
A. Beneficial Impacts (specify separate benefits and source.)												
1) Value of increased outputs of goods and services	0.035	0.005	0.010	0.035	0.005	0.010	0.035	0.005	0.010	0.035	0.005	0.010
2) Value of output resulting from external economies	0.067	0.100	0.118	0.067	0.100	0.118	0.067	0.100	0.118	0.067	0.100	0.118
3) Value of output from use of unemployed or, underemployed resources in construction or installation												
4) Total NED benefits	0.102	0.105	0.128	0.102	0.105	0.128	0.102	0.105	0.128	0.102	0.105	0.128
B. Adverse impacts (specify separate costs and source).												
1) Project costs												
2) Losses resulting from external diseconomies												
3) Total NED costs	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095
C. Net NED costs												
D. B/C Ratio	1.07	1.11	1.35	1.07	1.11	1.35	1.07	1.11	1.35	1.07	1.11	1.35

TABLE E-7 SYSTEM OF ACCOUNTS (CONT.)

	PLAN A (Cont'd)				PLAN B (Cont'd)				PLAN C (Cont'd)				PLAN D (Cont'd)			
	Within the Immediate Planning Area	Within the Rest of the Study Area	Within a Larger Area Affected by the Plan	Within the Rest of the Nation	Within the Immediate Planning Area	Within the Rest of the Study Area	Within a Larger Area Affected by the Plan	Within the Rest of the Nation	Within the Immediate Planning Area	Within the Rest of the Study Area	Within a Larger Area Affected by the Plan	Within the Rest of the Nation	Within the Immediate Planning Area	Within the Rest of the Study Area	Within a Larger Area Affected by the Plan	Within the Rest of the Nation
2. ENVIRONMENTAL QUALITY																
A. Environmental quality enhanced (specify resources impacted and quantify as possible)	Preservation of 930 acres of land of open space through groundwater & surface water development	Aesthetically pleasing	No Effect	No Effect	No new reservoirs required	Triburaties to Merrimack may experience higher summer flows.	No Effect	No Effect	No new reservoirs required	Tributaries to Merrimack may experience higher summer flows.	No Effect	No Effect	No new reservoirs required. More efficient use of a natural resource	Tributaries may experience higher summer flows.	No Effect	No Effect
B. Environmental quality degraded (specify resources impacted and quantify as possible)	Change in land use patterns by water supply development	Tributaries to Merrimack River may experience lower summer flows	No Effect	No Effect	Land use change along River for treatment plant.	River fluctuations due to increased draft. (Occurs only in reach between intake and STP discharge).	No Effect	No Effect	Land use change along river for treatment plant.	Increased river fluctuations due to increased draft. (w/in Mass. river reaches)	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect
C. Environmental quality destroyed (specify resources impacted and quantify as possible)	Inundation of approximately 340 acres of land for reservoirs will destroy terrestial ecology	No Effect	No Effect	No Effect	Loss of wildlife habitat due to development pressures	No Effect	No Effect	No Effect	Loss of wildlife habitat due to development pressures	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect

TABLE E-7 SYSTEM OF ACCOUNTS (CONT.)

	PLAN A (Cont'd)				PLAN B (Cont'd)				PLAN C (Cont'd)				PLAN D (Cont'd)			
	Within the Immediate Planning Area	Within the Rest of the Study Area	Within a Larger Area Affected by the Plan	Within the Rest of the Nation	Within the Immediate Planning Area	Within the Rest of the Study Area	Within a Larger Area Affected by the Plan	Within the Rest of the Nation	Within the Immediate Planning Area	Within the Rest of the Study Area	Within a Larger Area Affected by the Plan	Within the Rest of the Nation	Within the Immediate Planning Area	Within the Rest of the Study Area	Within a Larger Area Affected by the Plan	Within the Rest of the Nation
3. SOCIAL WELL-BEING																
A. Beneficial Impacts (specify and quantify as possible).																
1) Enhancement of health, safety, and community well being.	Limiting risk of regional contamination, maintains community identity. Allows public garden/pools.	No Effect	No Effect	No Effect	High degree of treatment insures water quality.	No Effect	No Effect	No Effect	High degree of treatment insures water quality	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect
2) Educational, cultural and recreational opportunities	Maintains social viability of area Possible recreational effects.	Possible recreational (swimming & wading) opportunities	No Effect	No Effect	Maintains social viability of area Possible recreational effects.	Possible recreational (swimming & wading) opportunities	No Effect	No Effect	Maintains social viability of area Possible recreational effects.	Possible recreational (swimming & wading) opportunities	No Effect	No Effect	May initiate broader understanding of resource conservation	No Effect	No Effect	No Effect
B. Adverse impacts (specify and quantify as possible)																
1) Deterioration in quality of life, health and safety.	Water quality will vary among communities	No Effect	No Effect	No Effect	Construction of pipelines will disrupt traffic	Construction of pipelines will disrupt traffic	No Effect	No Effect	Construction of pipelines will disrupt traffic	Construction of pipelines will disrupt traffic	No Effect	No Effect	Water use habits must be changed	No Effect	No Effect	No Effect
2) Degraded educational, cultural, and recreational opportunities	No Effect	No Effect	No Effect	No Effect	Passive recreational opportunity lost along river bank in Tyngsborough	Passive recreational opportunity lost along river bank in Tyngsborough	No Effect	No Effect	Passive recreational opportunity lost along river bank in Tyngsborough	Passive recreational opportunity lost along river bank in Tyngsborough	No Effect	No Effect	Plan will not provide water for public gardens/pools	No Effect	No Effect	No Effect
3) Injurious displacement of people and community disruption	Reservoir in Haverhill will remove 26 acres of conservation land.	No Effect	No Effect	No Effect	Institutional conflicts	No Effect	No Effect	No Effect	Institutional conflicts & expansion of Lawrence WTP will cause disruption of neighborhood.	No Effect	No Effect	No Effect	Plan will not provide water to meet demands	No Effect	No Effect	No Effect.

[1] Regional plan

[2] Sub-regional plan

[3] Annual electrical charges in excess of those required by the local options alternative.

[4] Annual employment wages.

TABLE E-7 SYSTEM OF ACCOUNTS (CONT.)

	PLAN A (Cont'd)							
	Within the Immediate Planning Area		Within the Rest of the Study Area		Within a Larger Area Affected by the Plan		Within the Rest of the Nation	
4. REGIONAL DEVELOPMENT	1970	1990	1970	1990	1970	1990	1970	1990
A. Beneficial impacts (specify separate benefits and source)								
1) Value of increased income	1.368[4]	3.881	3.109	7.600	16.03	36.66	553.0	1372
2) Quantity of increased employment	0.21	0.289	0.492	0.593	2.279	2.813	85.90	109.6
3) Desirable population distribution	0.49	0.707	1.135	1.394	5.261	6.449	204.9	258.7
4) Increased stability of regional economic growth	Water Resource Development Will Have a Positive Effect Upon Economic Growth when Water is Considered as Part of a Set of Resources.							
B. Adverse impacts (specify separate costs and source)								
1) Value of income lost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2) Quantity of jobs lost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3) Undesirable growth	Some Communities May View Growth as Undesirable. Therefore, Any Project Which Allowed/Encouraged Growth Would be Viewed as Undesirable Also.							

	PLAN B (Cont'd)							
	Within the Immediate Planning Area		Within the Rest of the Study Area		Within a Larger Area Affected by the Plan		Within the Rest of the Nation	
4. REGIONAL DEVELOPMENT	1970	1990	1970	1990	1970	1990	1970	1990
A. Beneficial impacts (specify separate benefits and source)								
1) Value of increased income	1.368	3.881	3.109	7.600	16.03	36.66	553.0	1372
2) Quantity of increased employment	0.21	0.289	0.492	0.593	2.279	2.813	85.90	109.6
3) Desirable population distribution	0.49	0.707	1.135	1.394	5.261	6.449	204.9	258.7
4) Increased stability of regional economic growth	Water Resource Development Will Have a Positive Effect Upon Economic Growth when Water is Considered as Part of a Set of Resources.							
B. Adverse impacts (specify separate costs and source)								
1) Value of income lost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2) Quantity of jobs lost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3) Undesirable growth	Some Communities May View Growth as Undesirable. Therefore, Any Project Which Allowed/Encouraged Growth Would be Viewed as Undesirable Also.							

	PLAN C (Cont'd)							
	Within the Immediate Planning Area		Within the Rest of the Study Area		Within a Larger Area Affected by the Plan		Within the Rest of the Nation	
4. REGIONAL DEVELOPMENT	1970	1990	1970	1990	1970	1990	1970	1990
A. Beneficial impacts (specify separate benefits and source)								
1) Value of increased income	1.368	3.881	3.109	7.600	16.03	36.66	553.0	1372
2) Quantity of increased employment	0.21	0.289	0.492	0.593	2.279	2.813	85.90	109.6
3) Desirable population distribution	0.49	0.707	1.135	1.394	5.261	6.449	204.9	258.7
4) Increased stability of regional economic growth	Water Resource Development Will Have a Positive Effect Upon Economic Growth when Water is Considered as Part of a Set of Resources.							
B. Adverse impacts (specify separate costs and source)								
1) Value of income lost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2) Quantity of jobs lost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3) Undesirable growth	Some Communities May View Growth as Undesirable. Therefore, Any Project Which Allowed/Encouraged Growth Would be Viewed as Undesirable Also.							

	PLAN D (Cont'd)							
	Within the Immediate Planning Area		Within the Rest of the Study Area		Within a Larger Area Affected by the Plan		Within the Rest of the Nation	
4. REGIONAL DEVELOPMENT	1970	1990	1970	1990	1970	1990	1970	1990
A. Beneficial impacts (specify separate benefits and source)								
1) Value of increased income	1.368	3.881	3.109	7.600	16.03	36.66	553.0	1372
2) Quantity of increased employment	0.21	0.289	0.492	0.593	2.279	2.813	85.90	109.6
3) Desirable population distribution	0.49	0.707	1.135	1.394	5.261	6.449	204.9	258.7
4) Increased stability of regional economic growth	Water Resource Development Will Have a Positive Effect Upon Economic Growth when Water is Considered as Part of a Set of Resources							
B. Adverse impacts (specify separate costs and source)								
1) Value of income lost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2) Quantity of jobs lost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3) Undesirable growth	Some Communities May View Growth as Undesirable. Therefore, Any Project Which Allowed/Encouraged Growth Would be Viewed as Undesirable Also.							

SECTION F

THE SELECTED SHORT TERM PLAN

1. This section of Appendix 1 is concerned with describing the short term plan selected from the previous section on plan formulation. All meaningful effects of the plan, both favorable and unfavorable, are presented. Of all alternatives considered, the plan presented appears to meet most satisfactorily the planning objectives of the Principles and Standards for the short term needs. Pertinent information on location and types of facilities are described to allow an understanding of the technical aspects of the plan.

PLAN DESCRIPTION

2. The most appropriate plan for the short term is a combination of non-structural and structural measures. The non-structural measures are consumer education and the use of water saving appliances; the structural measures are those required for each community to pursue its local option. This would mean that various courses of action, ranging from in town reservoir development to groundwater development to connection with the MDC or community interconnections, are required to be followed. Plate 17 indicates the proposed course(s) of action for each community. A more detailed description of these actions, their estimated costs and the estimated effect of water conservation is contained in the following list:

a. Acton - Corps of Engineers review indicates an additional 2.1 mgd of groundwater may be able to be developed; the development should allow the community to meet its estimated 2000 average day demand. It is estimated that five (5) wells will be required by 1976 to develop this potential, at a total development cost of $970,000. Annual costs would amount to $290,000.

b. Amesbury - By developing the Powwow River, the community could add approximately 2.7 mgd to its existing 3.0 mgd sources of supply. This development, requiring a new reservoir, intake works and diversion piping, would allow the community to meet its estimated 2020 maximum day demands. The estimated cost for this development which will be required by 1986 is $5,2000,000. Annual costs would be $525,000.

c. Andover - Community has just completed a 12 mgd water treatment facility, easily expandable to 18 mgd and then to 24 mgd if required. It has been assumed that North Andover and Tewksbury would be served by this facility and this would require the plant to expand to 18 mgd. This expansion would be required by 1989 and would allow all communities to meet their 2020 average day demand. The total construction cost for Andover, North Andover and Tewksbury is $1,390,000. Annual costs are $278,000. Andover's share of these costs is a legal matter and would be contingent on water useage, and agreements between the respective communities.

d. Bedford - Report has been completed for the MDC which outlined procedure for community to tie into the MDC system. Such a connection would allow Bedford to meet its demands through the planning period. Capital cost for this connection with the MDC is estimated to be $2,423,000. The connection will be required by 1976. Annual costs would be $310,000.

e. Billerica - Community has its 7 mgd water treatment facility on the Concord River being expanded to 14 mgd at the present time. Flow in the river is expected to increase during low flow periods because of the EPA-State implementation plan. As a result, the Concord River, which is the water supply source for the town, and the expanded water treatment facility, should allow the town to meet its estimated 2020 maximum day demand.

f. Boxford - At the present time, there is no public water supply system within the community. However, Corps of Engineers review indicates that approximately 3 mgd of groundwater may be developed which would allow the community to meet its estimated 2020 maximum day demand.

g. Carlisle - At the present time, this community is not serviced by any public water supply system, nor is one planned for the near future. Corps of Engineers review would indicate that sufficient groundwater is available for the community to meet its anticipated 2000 day demands.

h. Chelmsford - Community presently has four public water supply systems, all of which depend upon groundwater for their sources of supply. Corps of Engineers review would indicate that available groundwater has been developed; it has, therefore, been assumed that the four districts would combine and purchase water from an expanded Lowell water treatment facility, which would be required by 1978. Total construction costs for the Sub-Regional system of Lowell, Dracut, Chelmsford and Tyngsborough will be $12,944,000. Annual costs would be $1,435,000. Chelmsford would pay a certain portion of these costs. Their cost is a legal matter and would be determined with respect to certain factors such as water useage, connecting pipeline, and agreements between the communities.

i. Concord - Community now utilizes both ground and surface water supplies. Assuming that the surface water quality is maintained, and the additional 0.8 mgd of groundwater, which Corps of Engineers review indicates is available, the Community will be able to meet its estimated 2000 average day demands. Development of this groundwater is anticipated to require three (3) wells by 1990 at a total development cost of $585,000. Annual costs would be $164,000.

j. Dracut - A portion of the community is presently supplied by Lowell, another portion has a public water supply system and the remainder of the town relies upon on-lot sources of supply. It has been assumed that Lowell would continue to service any future water deficient areas within the town.

k. Dunstable - Town has a small water district which supplies approximately 40 percent of the community's population. Corps of Engineers review would indicate that development of potential groundwater will allow community to meet its estimated 2000 average day demand, assuming ratio of percent served to total population remains at its present rate.

l. Georgetown - Community presently supplies the Byfield section of Newbury, and uses groundwater as its source of supply. Corps of Engineers review would indicate an additional 2.2 mgd of groundwater is available to be developed. This development would allow all the communities to meet their anticipated 2020 maximum day demands. Development will be required by 1983. The cost of developing the additional groundwater is estimated to be $1,106,000. Annual costs would be $290,000.

m. Groveland - Presently serves town of West Newbury. Groundwater is source of supply, and if additional 1.1 mgd of groundwater is developed which has been identified by Corps of Engineers review, the communities will be able to meet estimated 2000 average day demands, but will not be able to meet estimated 1990 maximum day demands. Additional in town storage facilities may be required. Total construction costs for Groveland and West Newbury developments is $2,236,000. Annual costs would be $535,000. These developments will be required by 1976.

n. Haverhill - Report to City indicates that development of Little River, which would include a new reservoir, diversion and appurtenant works, coupled with new intake works at the existing reservoirs, and construction of an 18 mgd water treatment facility at Kenoza Lake, would allow the community to meet its estimated 2020 maximum day demands. These projects would be required by 1978. The total construction cost of all recommendations, including an 18 mgd water treatment, new intake works and Little River development, is estimated to be $21, 800,000. Annual costs amount to $1,937,000.

o. Lawrence - City presently serves entire town of Methuen in addition to itself under a contract which expires in 1980. The source of supply is the Merrimack River, and it is treated in a treatment facility rated at 14.5 mgd capacity. This facility is presently operated at capacity during the peak summer months, and requires approximately a 60% expansion if both communities are to be serviced through the 1990's. Each community has had engineering reports done to determine the most equitable approach to the water supply situation. For the purposes of this report, it has been assumed that Lawrence would continue to service Methuen past the present contract expiration date, i.e., a new contract would be entered into between Lawrence and Methuen. The construction cost for a 60 percent plant expansion which will be required by 1980 is estimated to be $9,770,000, with total annual costs of $900,000. The apportionment of costs would be determined at the time of the new agreement. If Methuen should construct its own treatment facility, then the initial construction costs for Methuen would be $6,690,000 with annual costs of $971,000. Lawrence would expand its facility by 20 percent, with an estimated expansion cost of $3,836,000 and additional annual costs of $539,000.

p. Littleton - Community's source is groundwater with a rated existing safe yield of 1.8 mgd. Town feels adequate groundwater available in western area of community, mainly due to town of Ayer's newly developed well in that vicinity. Corps of Engineers review of available geologic data is not supportive of this assumption. However, the town has authorized test borings to determine validity of its assumption, it can therefore be assumed Town will pursue groundwater development to meet its needs, at least through the short term, or until such resources are fully utilized. Estimated development cost for groundwater to supply the maximum day needs through the year 1990 are $920,000, with annual costs estimated at $109,000.

q. Lowell - Present source of supply is the Merrimack River, and the water is treated in a facility with a rated capacity of 10.5 mgd. This capacity has been equalled or exceeded in past summers. The city presently serves a portion of Dracut, and has received a request from one of the water districts in Chelmsford to purchase water. A report has been prepared for the city recommending expansion of its water treatment facility to 30 mgd capacity so it could accommodate itself as well as some of the surrounding communities, such as Chelmsford, Dracut, Tyngsborough, and possibly Tewksbury, at least through the year 1990. Total construction cost for this project, assuming Tewksbury purchases water from Andover, is estimated to be $12,944,000. Annual costs will be $1,435,000. The project will be required by 1978. Lowell's cost is a legal matter and is dependent on consumation of an agreement between the municipalities.

r. Merrimack - Present source is groundwater, with an existing rated safe yield of 1.0 mgd. Corps of Engineers review indicates an additional 0.6 mgd of groundwater is able to be developed. This development will be required by 1980 and would allow the community to meet its estimated 2020 average day demands. The cost for the estimated 2 new wells which would be required for this development is $387,000. Annual costs amount to $234,000.

s. Methuen - No source of supply of its own at present time because it is entirely served by City of Lawrence. An engineering report is being prepared for the Town to determine the most feasible way of supplying itself past the 1980 contract expiration date it has with Lawrence. For the purpose of this report, it has been assumed that the City of Lawrence will continue to supply the Town of Methuen past the present contract expiration date. However, should the Town construct its own facility, the initial construction cost is estimated to be $6,690,800 with annual costs estimated at $971,000.

t. Newbury - The Byfield section of Newbury has groundwater sources with an existing safe yield of 0.4 mgd. It is also serviced by Georgetown. Corps of Engineers review of available geologic data indicates that no further well development in Newbury is possible, but that with continuing supply from Georgetown, assuming Georgetown fully develops its groundwater potential, both communities will be able to meet estimated 2020 maximum day demands. The Old Town section of Newbury is presently wholly supplied by Newburyport. The Old Town Water District has been formed to determine if potential exists for supplying itself and possibly the Plum Island section. Corps of Engineers review would indicate a possible groundwater potential of 0.8 mgd may be developed within the Old Town section of Newbury; this development would allow Old Town to meet its estimated 2020 average day demands, but it would not be able to meet its estimated 2000 maximum day demand. For the purposes of this report, it has been assumed that Old Town would continue to be supplied by Newburyport, but that its groundwater potential would be developed. Costs for Old Town are therefore, given as part of the Newburyport costs. Apportionment of costs would be a matter of legal agreement.

u. Newburyport - Community has mixed ground and surface water supplies with an existing combined safe yield of 3.35 mgd. The water is treated in a 3.0 mgd capacity water treatment facility. An engineering report has recommended raising Artichoke Reservoir so that an additional 2.65 mgd of safe yield could be realized. Much of the land acquisition for this raising has been accomplished; therefore, it has been assumed that Newburyport will pursue this course of action. The total construction cost for expansion of the Newburyport system and development of groundwater in Old Town has been estimated at $5,366,000. Annual costs amount to $632,000. The improvement will be required by 1976.

v. North Andover - With the large water treatment facility which Andover has constructed, it has been assumed that Andover would supply North Andover through the study period. The construction cost for the entire system of Andover, North Andover, and Tewksbury is estimated to be $1,390,000. Annual costs are expected to be $278,000. North Andover's share of these costs is a legal matter and will depend upon the amount of water purchased, construction of a connecting pipeline, etc., and agreement between the communities. The system will be required by 1989.

w. Pepperell - Groundwater serves as community's source of supply with an existing safe yield of 1.7 mgd. Town feels this source will be adequate beyond the year 2000. Corps of Engineers review with its population and water usage forecasts is not supportive of this view as estimated 1990 average demand is 2.2 mgd. However community action could affect these forecast levels.

x. Rowley - Groundwater is the source of supply for this community, with an existing safe yield of 0.7 mgd. Corps of Engineers review indicates availability of groundwater to supply this community beyond the study period. Groundwater development costs to allow Rowley to meet its estimated 2020 maximum day demands is $585,000. Annual costs would be $158,000. The additional groundwater will be required by 1987.

y. Salisbury - Community is served by a private water company which has developed groundwater as its source of supply. Corps of Engineers review and discussions with the water company indicate that sufficient capacity is available at the present time to at least meet anticipated 1990 maximum day demands, and 2020 average day demands.

z. Tewksbury - Due to the community's immediate need for additional water, and the relative nearness of the Andover water treatment facility, it has been assumed that Tewksbury would purchase processed water from Andover. If, however, this is not possible, a connection with Lowell, after Lowell expands its plant, is a viable alternative. Total construction cost for the Sub-Regional system of Andover, North Andover, and Tewksbury is expected to be $1,390,000. Annual costs amount to $278,000. Tewksbury's share of these costs is once again a legal matter and contingent upon connecting pipelines, water useage and agreements made by the communities.

aa. Tyngsborough - It has been assumed that the community will purchase water from the expanded Lowell system when a municipal system is required. The relatively short distance between the Lowell water treatment plant site and the population center of Tyngsborough makes this a realistic assumption. Tyngsborough's share of the Lowell, Dracut, Chelmsford and Tyngsborough system is a legal matter and will depend on water usage, connecting pipelines and necessary agreements. The system will be required by 1978.

bb. Westford - Community is presently supplied by groundwater sources which have an estimated safe yield of 4.8 mgd. Corps of Engineers review of available data indicates an additional 1.8 mgd of potential groundwater available. Development of this potential will be required by 1990 and is estimated to cost $774,000. Annual costs are $234,000, and will allow the community to meet its estimated 2020 maximum day demands.

cc. West Newbury - Community presently served by Groveland, however, Corps of Engineers review would indicate a potential groundwater supply of 0.9 mgd could be developed. West Newbury's portion of the total construction and annual costs of its system with Groveland would be determined in a legal fashion. Total construction costs amount to $2,236,000 and annual costs are expected to be $535,000. This development would allow West Newbury to meet its estimated 2000 maximum day demand; however, because both communities are interconnected, they will not be able to meet estimated 1990 maximum day demands. The improvements will be required by 1976.

3. The use of water saving appliances, if these appliances are replaced upon obsolescence or installed in new housing, coupled with consumer water conservation efforts, can impact upon the anticipated water demands. This total conservation impact for the study area as a whole was estimated* to be about 8.3 percent reduction by the year 1990, and about 9.0 percent by the year 2020. This reduction would not relieve these communities from expanding their sources of supply, but it would allow the facilities described above to serve for about an additional five years before new supplies would be needed.

PLAN ACCOMPLISHMENTS

4. Timely implementation of the selected short term plan will allow the region to meet its estimated water demands by allowing each community to fully develop, in the most efficient manner, its water resource. No large regional institutions are required, although small-scale municipal interconnections will be. Open space will be created by reservoir construction and groundwater development. Industrial expansion would be allowed which could have a significant economic

* Water Demand Study, Eastern Massachusetts Region, Prepared for New England Division, Corps of Engineers, by Coffin and Richardson, Inc., Boston, Massachusetts, November 1974.

impact on the area by reducing the high unemployment rate. Additionally, each community will be more able to plan for and direct its own growth.

EFFECTS OF THE PLAN

5. The selected short term plan is the least costly economically overall and meets most efficiently the National Economic Development objective. Some individual communities may pay more for their water under the Local Option plan than under either the Regional or Sub-Regional Systems. Of all the communities studied, only the Groveland-West Newbury system lacks the potential resources to meet anticipated 1990 maximum day demands. An emergency connection now exists between Haverhill and Groveland, and, with the anticipated improvements to the Haverhill system, the short term demands could be easily met.

6. From an Environmental Quality standpoint, implementation of this plan will have less of an effect upon the Merrimack River than either the Regional or Sub-Regional alternative. The Concord River may experience low flows in the reach between the Billerica water treatment plant intake and the wastewater treatment plant discharge, prior to the period when the State-EPA water pollution control program is implemented. After implementation, however, there should be sufficient river flowage between the intake and discharge of the respective plants. The plant also recommends the damming and ponding of the Little River in Haverhill and the Powwow River in Amesbury.

7. The environmental considerations allied with the construction of these reservoirs such as the effects of the impoundment and downstream impacts will be addressed by the communities involved. In addition, the raising of the existing Artichoke Reservoir will also impact on the environment in the immediate vicinity of the reservoir. All three local reservoir proposals are in town developments however, and the majority of project related impacts can be expected to occur in the municipality which will utilize the facility.

8. Additional groundwater development would be the supply source for a number of communities in the plan. In general such groundwater

development is considered to cause the least environmental impacts. In order to utilize this resource however, communities must maintain adequate recharge areas and prevent contamination of the aquifers. Since many of the tributary streams in the basin are highly dependent on groundwater discharge for their flows during low flow periods, care must be taken in the development of the ground water wells. As noted for the surface water developments, environmental impacts associated with well fields can principally be expected in those towns which would use the resource. Therefore the beneficiary of the development will be most closely associated with its environmental costs.

9. The water demand modification component of the recommended plan is in consonance with environmental quality. The educational aspects of the demand modification component together with the use of water saving appliances should nurture an appreciation for the water resource and the role which conservation plays in maintaining the quality of the environment.

10. With regard to the social well-being objective, the plan encourages full development of local resources, which is socially acceptable. Intercommunity connections, especially for those communities which abut communities with existing treatment facilities using the Merrimack River as a source, will become more prevalent as increasing populations and per capita water demands tend to exhaust the local resources of the smaller communities. This course of action, however, allows each community to decide for itself whether or not water will help to limit or constrain growth. Because water is for the most part available to all communities, those communities having immediate needs can pursue plans to fully develop their own resources, and not have to worry about the implementation of a large regional system which would negate full local development. The implementation of the plan which relies to a large measure on local action would not require formation of a regional management commission. Institutional arrangements for its implementation are therefore minimized.

11. The Regional Development objective also appears to be well served by the selected plan. Timely implementation of the selected plan will insure an adequate supply of potable water for the region. As indicated previously, the size limitation of the Lowell water treatment facility has prevented the expansion of several industries resulting in a loss of approximately 6900 prospective job opportunities. If all of these potential jobs could be filled, it would halve the preset unemployment

rate in Lowell. This is a significant consideration given the current high rate which Lowell is experiencing. An aesthetically pleasing region will at least maintain, or possibly raise, property values due to the allowance of lawn and garden care, public parks and recreation areas. The selected plan also allows each community the choice of whether or not water supply will be a growth deterrant.

SECTION G

FORMULATING ALTERNATIVE PLANS FOR THE LONG TERM

1. The formulation of plans to meet the estimated long term water supply needs of the in-basin and out-of-basin communities, identified as requiring supply augmentation by the year 2020, is complicated by the time frame which the plans are to address. Extrapolation of past trends to estimate future conditions is the most common and best accepted prediction method. However, predictions for so far into the future are intended only to show orders of magnitude, and not to yield specific numbers. This is so because change, other than that caused by natural catastrophies, develops slowly over time, and there is no way of developing a prediction model that can " sense" a pending change due to input (existing) data. Therefore, the formulation and evaluation criteria are applied with the knowledge that both the needs and the methods of meeting those future needs may be different than those indicated by case of the present day criteria. Alternatives will be presented and screened in much the same manner as with the short term alternatives; however, no final selection will be made. Rather, after the initial screening, the remaining alternatives, with all known beneficial, neutral or adverse effects will be displayed. This display can then be used as a starting point for future studies at the appropriate time.

2. The study area for the long term plan includes communities presently served by the MDC, those communities anticipated to join the MDC by 1990, and communities, or groups thereof, whose demands will outstrip their capability to supply themselves by the year 2020. The counties involved-- Bristol, Essex, Middlesex, Norfolk, Plymouth, Suffolk, and Worcester--accounted for approximately 83 percent of Massachusetts total population in 1970, with 4, 749, 537 people, and are estimated to account for approximately 82 percent of the state's total population in the year 2020 with 6, 518, 387 people.

3. The following table lists, by county, the communities which could be anticipated to be served by a regional system, their estimated total safe yield (unless 100 percent served by MDC at present), the estimated 2020 population, and the estimated average and maximum day demands for 2020.

4. For the long term an expanded MDC system is seen as the basis of any regional water supply system serving Eastern Massachusetts. The demand on this system is estimated to be approximately 660 mgd by the year 2020. The implementation of the Northfield Mountain and Millers River Basin diversions from the Connecticut River Basin to the Quabbin Reservoir will increase the safe yield of the Quabbin-Wachusett system to approximately 450 mgd. This means that an additional 210 mgd of water will be required by the year 2020 to meet this estimated demand. The Merrimack River has been proposed as a viable alternative for meeting this need and along with other alternatives is the subject of this section of the report.

NON-STRUCTURAL

NO DEVELOPMENT

5. As previously indicated, the study area population is estimated to increase fromabout 4.7 million in 1970 to 6.5 million in 2020. The area includes metropolitan Boston, the industrial belt along Route 128 and all of the major cities in eastern Massachusetts. The estimated deficit of this area in 2020 is anticipated to equal 210 mgd, as illustrated on Table G-1. For the many reasons listed under the short term No Development scenario--namely, inadequate fire protection, institutional restrictions, tax base erosion, and other social and economic impacts--it follows that this deficit should be met, reduced or a combination thereof. If No Development is defined as a "do nothing" policy, it is not considered a viable alternative for an area such as the study area.

WATER DEMAND MODIFICATION

6. A study,* prepared for use in this report, investigated the possibility of reducing domestic water demands through various techniques. As described earlier, it had been anticipated that pricing would hold great promise as a demand modification technique to reduce household use. However, the data collected indicated costs ranging from approximately

* Water Demand Study, Eastern Massachusetts Region. Prepared for the New England Division, Corps of Engineers by Coffin and Richardson, November, 1974

TABLE G-1

FUTURE POPULATIONS & WATER DEMANDS OF BRISTOL COUNTY, ESSEX COUNTY, MIDDLESEX COUNTY, NORFOLK COUNTY, PLYMOUTH COUNTY, SUFFOLK COUNTY AND WORCESTER COUNTY

BRISTOL COUNTY - TOWNS EXCLUSIVE OF MDC

Community	Total Safe Yield	Population 1970	Population 2020	2020 Water Demands Average Day	2020 Water Demands Maximum Day	2020 Deficits Average Day	2020 Deficits Maximum Day
Acushnet	0.36	7,703	11,451	1.6	2.8	See Note 1	See Note 1
Attleboro	10.00	32,226	52,300	17.5	24.0	See Note 1	See Note 1
Berkley	Private Wells	2,022	3,089	0.4	0.8	See Note 1	See Note 1
Dartmouth	1.50	18,691	21,095	3.5	5.7	See Note 1	See Note 1
Dighton	0.62	4,635	6,884	1.1	2.0	See Note 1	See Note 1
Easton	3.80	12,249	21,434	2.9	4.9	See Note 2	See Note 2
Fairhaiven	1.31	16,371	19,176	2.6	4.4	See Note 1	See Note 1
Fall River	16.50	95,679	98,058	21.0	28.0	See Note 1	See Note 1
Freetown	0.36	4,255	7,850	1.0	1.9	See Note 1	See Note 1
Mansfield	3.18	9,927	15,732	4.3	6.9	See Note 1	See Note 1
New Bedford	20.50	101,262	107,044	44.0	54.0	See Note 1	See Note 1
North Attleboro	4.50	18,455	28,824	4.5	7.2	See Note 1	See Note 1
Norton	2.00	9,425	19,056	2.7	4.5	See Note 1	See Note 1
Raynham[11]	1.09	6,659	13,253	1.6	2.9	0.51	1.81
Rehoboth	Private Wells	6,447	10,309	1.3	2.4	-	-
Seekonk	3.00	11,056	17,112	2.6	4.4	0	1.40
Somerset	5.27	18,122	26,354	4.4	7.0	0	1.73
Swansea	2.80	12,525	17,431	2.3	3.9	0	1.10
Taunton	9.50	43,766	52,684	12.0	18.0	See Note 1	See Note 1
Westport	Private Wells	9,655	15,619	2.0	3.5	See Note 1	See Note 1
TOTALS	85.93	441,130	564,755	133.3	189.2	0.51	6.04

1) Southeastern Massachusetts Water District (SEMWAD) will serve these communities.
2) Old Colony Regional Planning System (OCRPS) will serve these communities, but will need source augmentation by the year 2020; therefore, this augmentation assumed met by the regional system.
11) Assumed served by regional system.

TABLE G-1 (Cont'd)
ESSEX COUNTY - TOWNS EXCLUSIVE OF MDC

Community	Total Safe Yield	Population 1970	Population 2020	2020 Water Demands Average Day	2020 Water Demands Maximum Day	2020 Deficits Average Day	2020 Deficits Maximum Day
Amesbury	5.70	11,333	19,500	2.6	4.5	0	0
Andover	20.50	23,277	39,000	11.0	16.0	See Note 3	See Note 3
Beverly	Served by Salem	38,073	66,192	-	-	See Note 4	See Note 4
Boxford	3.00	4,001	11,000	1.3	2.3	See Note 4	See Note 4
Danvers	4.20	26,133	39,199	7.4	11.2	See Note 4	See Note 4
(Serves Middleton)							
Essex	2.30	2,637	10,307	1.3	2.3	See Note 4	See Note 4
Georgetown	4.0	5,271	12,000	2.2	4.0	See Note 4	See Note 4
(Serves Byfield)							
Gloucester	4.00	27,690	41,023	8.4	12.5	See Note 4	See Note 4
Groveland	2.4	5,325	13,200	2.4	3.4	0	1.0
(Serves W. Newbury)							
Hamilton	4.60	6,374	19,056	2.6	4.4	See Note 4	See Note 4
Haverhill	18.00	45,643	61,100	12.5	18.0	0	0
Ipswich	1.70	10,853	22,598	3.4	5.6	See Note 4	See Note 4
Lawrence	22.40	66,216	71,000	17.7	26.1	0	0
(Serves Methuen)							
Lynn	17.0	87,816	101,532	26.0	34.0	See Note 4	See Note 4
Manchester	2.30	5,086	16,750	2.7	4.5	See Note 4	See Note 4
Merrimack	1.60	4,184	6,900	1.0	1.9	0	0.3
Methuen	Served by Lawrence	34,986	48,200	-	-	-	-
Middleton	Served by Danvers	3,954	9,147	-	-	See Note 4	See Note 4
Newbury							
Byfield	Served by Georgetown	1,890	3,300	-	-	-	-
Old Town	Served by Newburyport	1,890	3,300	-	-	-	-

TABLE G-1 (Cont'd)
ESSEX COUNTY - TOWNS EXCLUSIVE OF MDC (Cont'd)

Community	Total Safe Yield	Population 1970	Population 2020	2020 Water Demands Average Day	2020 Water Demands Maximum Day	2020 Deficits Average Day	2020 Deficits Maximum Day
Newburyport (Serves Old Town)	6.8	15,685	25,000	5.9	9.3	0	2.5
North Andover	3.00	16,185	29,400	5.3	8.3	See Note 3	See Note 3
Rockport	0.60	5,536	13,424	2.1	3.6	See Note 4	See Note 4
Rowley	1.30	3,006	5,700	0.6	1.3	See Note 4	See Note 4
Salem (Serves Beverly)	22.5	39,971	35,417	21.1	28.3	See Note 4	See Note 4
Salisbury	3.80	4,150	8,200	2.0	3.5	0	0
Topsfield	3.2	5,193	15,995	2.1	3.7	See Note 4	See Note 4
Wenham	2.90	3,818	12,409	1.5	2.7	See Note 4	See Note 4
West Newbury	Served by Groveland	2,228	4,000	-	-	-	-
TOTALS	157.8	508,404	763,849	143.1	211.4	0	3.8

3) Andover, North Andover and Tewksbury expected to form a small regional system.

4) To be served by Reservoir 30 B, which will require source augmentation by the year 2020; therefore, the regional system has been assumed to supply this augmentation.

TABLE G-1 (Cont'd)
MIDDLESEX COUNTY - TOWNS EXCLUSIVE OF MDC

Community	Total Safe Yield	Population 1970	Population 2020	2020 Water Demands Average Day	2020 Water Demands Maximum Day	2020 Deficits Average Day	2020 Deficits Maximum Day
Acton [11]	4.90	14,578	43,000	5.5	8.6	0.6	3.7
Ashby	Private Wells	2,241	5,400	0.4	0.8	-	-
Ayer	3.50	7,292	11,100	1.8	3.2	0	0
Bedford	3.30	13,473	17,800	3.4	5.6	See Note 7	See Note 7
Billerica	14.00	31,284	48,900	7.3	11.0	0	0
Boxborough	Private Wells	1,447	13,300	1.5	2.7	-	-
Burlington	7.73	22,114	32,300	5.7	8.8	0	0
Carlisle	Private Wells	2,863	20,400	2.3	4.0	-	-
Chelmsford	5.80	31,258	43,600	7.1	10.7	See Note 5	See Note 5
Concord	6.30	15,971	39,400	6.3	9.8	0	3.5
Dracut	Served by Lowell	18,220	37,200	-	-	See Note 5	See Note 5
Dunstable	Private Wells	1,273	18,000	2.2	3.8	-	-
Groton [11]	1.51	5,011	11,700	3.0	4.9	1.49	3.39
Hopkinton [11]	1.30	5,943	24,400	2.9	4.9	1.6	3.6
Littleton [11]	3.20	6,296	20,300	3.8	6.1	0.6	2.9
Lowell (Serves Dracut)	32.7	92,929	100,800	20.3	29.0	See Note 5	See Note 5
North Reading	1.77	11,152	21,003	2.8	4.7	See Note 6	See Note 6
Pepperell	3.80	5,795	27,300	4.5	7.2	0	3.4
Reading	6.44	22,534	34,319	5.2	8.2	See Note 6	See Note 6
Shirley	1.20	4,851	7,800	0.6	1.2	0	0
Tewksbury	3.30	22,464	39,600	5.1	8.1	See Essex County Note [3]	See Essex County Note [3]

TABLE G-1 (Cont'd)
MIDDLESEX COUNTY - TOWNS EXCLUSIVE OF MDC (Cont'd)

Community	Total Safe Yield	Population 1970	Population 2020	2020 Water Demands Average Day	2020 Water Demands Maximum Day	2020 Deficits Average Day	2020 Deficits Maximum Day
Townsend	2.71	4,228	10,000	1.0	1.9	0	0
Tyngsborough	Private Wells	4,167	23,200	2.8	4.7	See Note 5	See Note 5
Wayland	7.10	13,588	36,700	5.9	9.1	0	2.0
Westford	6.60	10,275	35,800	4.0	6.4	0	0
Wilmington	7.10	17,011	37,000	7.0	10.6	See Note 6	See Note 6
TOTALS	124.86	388,258	760,322	112.4	176.0	4.29	22.49

5) Lowell, Dracut, Chelmsford and Tyngsborough expected to form a small regional system.
6) To be served by Reservoir 30 B.
7) Bedford will join the MDC.
11) Assumed served by Regional system.

TABLE G-1 (Cont'd)
NORFOLK COUNTY - TOWNS EXCLUSIVE OF MDC

Community	Total Safe Yield	Population 1970	Population 2020	2020 Water Demands Average Day	2020 Water Demands Maximum Day	2020 Deficits Average Day	2020 Deficits Maximum Day
Bellingham	3.23	13,828	19,790	2.2	3.8	0	0.57
Foxborough	4.65	14,231	27,685	4.5	7.2	0	2.55
Franklin[11]	2.39	17,825	37,191	5.3	8.3	2.91	5.91
Medway[11]	1.77	7,896	16,400	2.1	3.7	0.33	1.93
Plainville	-	4,963	8,480	1.7	3.1	-	-
Sharon	5.07	12,510	27,210	3.6	5.8	0	0.73
Walpole[11]	6.80	18,152	44,666	7.6	11.4	0.8	4.6
Wrentham	2.70	7,272	22,110	2.7	4.6	0	1.9
TOTALS	26.61	96,677	203,532	29.7	47.9	4.04	18.19

[11] Assumed served by Regional System for this Report.

TABLE G-1 (Cont'd)
PLYMOUTH COUNTY - TOWNS EXCLUSIVE OF MDC

Community	Total Safe Yield	Population 1970	Population 2020	2020 Water Demands Average Day	2020 Water Demands Maximum Day	2020 Deficits Average Day	2020 Deficits Maximum Day
Abington (Serves Rockland)	5.85	12,382	19,467	5.0	7.9	See Note 2 Bristol County	See Note 2 Bristol County
Bridgewater	2.98	12,585	17,203	1.9	3.3	See Note 2 Bristol County	See Note 2 Bristol County
Brockton (Serves Whitman, Hanson)	18.16	87,444	143,122	27.8	39.2	See Note 2 Bristol County	See Note 2 Bristol County
Carver	Private Wells	2,389	3,824	0.5	1.0	-	-
Cohasset	3.49	6,943	15,935	2.3	3.9	0	0
Duxbury	4.46	7,625	15,376	2.5	4.2	0	0
East Bridgewater	1.40	8,311	13,016	1.7	3.0	See Note 2 Bristol County	See Note 2 Bristol County
Halifax	1.69	3,505	8,078	1.2	2.2	0	0.51
Hanover	4.48	10,102	23,339	3.2	5.2	0	0.72
Hanson	Served by Brockton	7,056	13,450	-	-	See Note 2 Bristol County	See Note 2 Bristol County
Hingham[11] (Serves Hull)	6.10	18,867	31,218	6.1	9.5	0	3.4
Hull	Served by Hingham	10,011	7,367	-	-	-	-
Kingston	3.34	5,941	10,006	1.8	3.2	0	0
Lakeville	Private Wells	4,324	6,785	0.9	1.7	See Note 1 Bristol County	See Note 1 Bristol County
Marion (Serves Rochester)	1.15	3,443	4,408	0.9	1.7	0	0.55
Marshfield	9.81	15,104	41,103	6.7	10.3	0	0.49
Mattapoisett	2.05	4,464	6,543	0.8	1.6	0	0
Middleborough	1.80	13,519	18,815	3.0	5.0	See Note 1 Bristol County	See Note 1 Bristol County

TABLE G-1 (Cont'd)
PLYMOUTH COUNTY - TOWNS EXCLUSIVE OF MDC (Cont'd)

Community	Total Safe Yield	Population		2020 Water Demands		2020 Deficits	
		1970	2020	Average Day	Maximum Day	Average Day	Maximum Day
Norwell	3.15	7,790	17,700	2.4	4.2	0	1.05
Pembroke	1.75	11,021	17,438	1.9	3.4	See Note 2 Bristol County	See Note 2 Bristol County
Plymouth	7.86	18,615	23,517	4.1	6.7	0	0
Plympton	Private Wells	1,221	2,528	0.3	0.7	-	-
Rochester	Served by Marion	1,745	1,753	-	-	-	-
Rockland	Served by Abington	15,566	19,164	-	-	-	-
Scituate	3.87	16,744	27,495	3.8	6.1	0	2.23
Wareham	3.92	11,098	13,284	2.5	4.3	0	0.38
West Bridgewater	1.90	7,089	17,483	2.0	3.5	See Note 2 Bristol County	See Note 2 Bristol County
Whitman	Served by Brockton	10,968	22,279	-	-	See Note 2 Bristol County	See Note 2 Bristol County
TOTALS	85.69	335,872	561,696	83.3	132.2	0	9.33

11) Assumed served by Regional system.

TABLE G-1 (Cont'd)
WORCESTER COUNTY - TOWNS EXCLUSIVE OF MDC

Community	Total Safe Yield	Population 1970	Population 2020	2020 Water Demands Average Day	2020 Water Demands Maximum Day	2020 Deficits Average Day	2020 Deficits Maximum Day
Ashburnham	0.50	3,483	6,300	0.5	0.9	0	0.4
Athol	3.5	11,086	10,306	1.17	2.16	0	0
Auburn	3.80	15,397	19,047	1.9	3.3	See Note 8	See Note 8
Barre [11]	1.07	3,827	4,460	1.5	2.65	0.43	1.58
Berlin	0.95	2,074	4,600	0.6	1.2	0	0.25
Blackstone	2.02	6,501	11,066	1.2	2.3	0	0.28
Boylston	1.30	2,745	6,000	0.75	1.5	0	0.2
Brookfield	0.05	2,063	2,873	0.2	0.4	See Note 9	See Note 9
Charlton	0.90	4,603	6,892	0.8	1.5	0	0.6
Douglas	0.79	2,920	3,750	0.5	0.9	0	0.11
Dudley	2.50	8,023	10,984	1.8	3.2	0	0.7
East Brookfield	0.19	1,826	2,570	0.4	0.8	See Note 9	See Note 9
Fitchburg [11]	13.3	42,906	43,600	14.5	20.3	1.2	7.0
Gardner	6.15	19,513	21,244	3.0	4.9	See Note 10	See Note 10
Grafton	1.20	11,664	14,649	1.7	3.05	See Note 8	See Note 8
Hardwick	0.28	2,357	3,095	0.2	0.5	0	0.22
Harvard	0.06	13,306	19,600	.03	.07	0	0.01
Holden	2.57	12,564	24,600	3.6	5.85	See Note 8	See Note 8
Hopedale	1.08	4,294	5,313	0.9	1.75	0	0.67
Hubbardston	Private Wells	1,423	2,366	0.3	0.6	-	-
Lancaster	2.00	6,055	11,900	1.5	2.7	0	0.7
Leicester	2.80	9,015	12,250	1.5	2.7	0	0
Lunenburg	4.75	7,396	19,500	1.6	2.9	0	0
Mendon	0.82	2,502	3,506	0.4	0.9	0	0.08

TABLE G-1 (Cont'd)
WORCESTER COUNTY - TOWNS EXCLUSIVE OF MDC (Cont'd)

Community	Total Safe Yield	Population		2020 Water Demands		2020 Deficits	
		1970	2020	Average Day	Maximum Day	Average Day	Maximum Day
Milford	4.40	19,299	26,141	3.6	5.9	0	0
Millbury	2.05	11,929	16,492	3.9	6.3	See Note 8	See Note 8
Millville	0.49	1,754	2,473	0.3	0.7	0	0.21
New Braintree	0.20	625	987	0.1	0.25	0	0.05
Northbridge	3.80	11,798	15,236	3.0	5.0	0	1.2
North Brookfield	1.50	3,953	5,806	0.8	1.5	0	0
Oakham	0.40	727	814	0.2	0.5	0	0.1
Oxford	2.65	10,392	15,464	1.2	2.3	0	0
Paxton	0.60	3,740	7,800	0.8	1.5	See Note 8	See Note 8
Petersham	Private Wells	1,010	1,286	0.15	0.35	-	-
Phillipston	Private Wells	860	1,392	0.16	0.37	-	-
Princeton	0.77	1,687	4,100	0.5	1.05	0	0.28
Royalston	Private Wells	799	949	0.1	0.24	-	-
Rutland	0.85	3,143	7,200	0.8	1.6	0	0.75
Shrewsbury	4.16	19,229	31,900	4.5	7.2	See Note 8	See Note 8
Southbridge	5.00	16,847	18,818	2.6	4.4	0	0
Spencer	1.70	8,795	11,508	1.2	2.1	0	0.4
Sterling	1.85	4,219	11,200	0.9	1.65	0	0.4
Sturbridge	1.30	4,892	7,064	1.0	1.8	0	0.5
Sutton	0.87	4,522	7,460	0.5	1.05	0	0.18
Templeton	1.25	5,799	7,462	1.25	2.3	0	1.05
Upton	0.67	3,455	4,074	0.65	1.3	See Note 8	See Note 8
Uxbridge	1.90	8,233	9,699	1.0	1.9	0	0
Warren	0.65	3,587	4,631	0.5	1.0	0	0.35
Webster	4.00	14,761	17,352	2.4	4.0	0	0

TABLE G-1 (Cont'd)
WORCESTER COUNTY - TOWNS EXCLUSIVE OF MDC (Cont'd)

Community	Total Safe Yield	Population 1970	Population 2020	2020 Water Demands Average Day	2020 Water Demands Maximum Day	2020 Deficits Average Day	2020 Deficits Maximum Day
Westborough	2.75	12,438	28,500	3.7	6.0	See Note 8	See Note 8
West Boylston	1.70	6,381	11,800	1.4	2.6	0	0.9
West Brookfield	0.66	2,639	3,537	0.5	0.9	0	0.24
Westminster	1.05	4,199	10,500	1.7	3.1	See Note 10	See Note 10
Winchendon	3.20	6,593	7,973	1.0	1.8	0	0
TOTALS	10.3	395,785	570,089	81.01	137.69	1.63	19.01

8) Connection to Worcester (MDC water) is available to augment their supply
9) Brookfield/East Brookfield System
10) Gardner/Westminster System
11) Assumed served by Regional system.

TABLE G-1 (Cont'd)
MDC AND TOWNS HAVING NO OPTION BUT TO BUY
WATER FROM THE MDC TO MEET 2020 DEMANDS

Community	Total Safe Yield	Population 1970	Population 2020	2020 Water Demands Average Day	2020 Water Demands Maximum Day	Amount of Water MDC Must Supply Average Day	Amount of Water MDC Must Supply Maximum Day
Arlington	MDC	52,720	53,039	9.2	13.6	9.2	13.6
Ashland	4.0	8,900	22,200	5.1	8.0	1.1	4.0
Avon	0.7	5,387	10,470	1.3	2.3	0.6	1.6
Belmont	MDC	27,750	27,216	3.9	6.3	3.9	6.3
Bolton	0	1,886	12,200	1.4	2.5	1.4	2.5
Boston	MDC	628,215	599,400	238.0	245.0	238.0	245.0
Braintree	2.8	35,373	52,213	8.9	13.2	6.1	10.4
Brookline	MDC	58,090	63,373	11.5	16.5	11.5	16.5
Cambridge	13.7	98,942	103,754	33.1	42.3	19.4	28.6
Canton	3.2	17,089	42,893	10.7	15.4	7.5	12.2
Chelsea	MDC	30,122	18,764	3.5	5.8	3.5	5.8
Chicopee	MDC	66,676	98,690	23.0	30.6	23.0	30.6
Clinton	MDC	13,270	15,100	4.1	6.7	4.1	6.7
Dedham (Serves Westwood)	7.7	27,233	29,860	8.2	12.2	0.5	4.5
Dover	0.2	4,495	14,915	1.9	3.4	1.7	3.2
Everett	MDC	42,216	31,686	12.5	17.7	12.5	17.7
Framingham	0.7	63,233	91,800	15.3	21.3	14.6	20.6
Holbrook	Served by Randolph	11,787	15,622	-	-	-	-
Holliston	1.9	12,116	25,700	2.9	4.9	1.0	3.0
Hudson	2.5	15,853	30,300	5.7	8.8	3.2	6.3
Leominster	6.9	32,709	52,700	16.6	22.9	9.7	16.0
Lexington	MDC	31,628	51,800	10.4	15.2	10.4	15.2
Lincoln	1.1	10,712	18,600	2.1	3.7	1.0	2.6
Lynnfield	1.2	10,718	16,000	2.1	3.7	0.9	2.5

TABLE G-1 (Cont'd)
MDC AND TOWNS HAVING NO OPTION BUT TO BUY
WATER FROM THE MDC TO MEET 2020 DEMANDS (Cont'd)

Community	Total Safe Yield	Population 1970	Population 2020	2020 Water Demands Average Day	2020 Water Demands Maximum Day	Amount of Water MDC Must Supply Average Day	Amount of Water MDC Must Supply Maximum Day
Malden	MDC	55,851	43,583	9.5	14.0	9.5	14.0
Marblehead	MDC	21,180	19,929	3.4	5.6	3.4	5.6
Marlborough	MDC	27,721	43,600	5.5	8.6	5.5	8.6
Maynard	0.4	9,551	12,900	3.2	5.3	2.8	4.9
Medfield	1.1	9,634	25,089	3.1	5.1	2.0	4.0
Medford	MDC	63,481	65,266	11.7	16.7	11.7	16.7
Melrose	MDC	32,881	39,028	5.7	8.9	5.7	8.9
Millis	1.0	5,672	19,328	3.0	5.0	2.0	4.0
Milton	MDC	27,011	42,779	6.4	9.8	6.4	9.8
Nahant	MDC	4,081	3,700	0.7	1.3	0.7	1.3
Natick	9.2	31,055	46,300	10.3	15.0	1.1	5.8
Needham	3.4	29,737	53,244	9.8	14.4	6.4	11.0
Newton	MDC	91,197	111,096	22.2	29.7	22.2	29.7
Norfolk	-	4,637	15,302	2.0	3.4	2.0	3.4
Northborough	1.0	9,253	19,900	2.9	4.9	1.9	3.9
Norwood	MDC	30,828	39,100	8.0	12.0	8.0	12.0
Peabody	6.0	45,000	56,155	12.9	18.4	6.9	12.4
Quincy	MDC	88,171	111,380	22.6	30.2	22.6	30.2
Randolph (Serves Holbrook)	3.8	27,117	31,290	6.0	9.2	2.2	5.4
Revere	MDC	42,634	44,477	6.4	9.8	6.4	9.8
Saugus	MDC	25,407	27,113	4.6	7.3	4.6	7.3
Sherborn	MDC	3,349	14,000	1.6	2.9	1.6	2.9
Somerville	MDC	87,047	68,590	12.2	17.4	12.2	17.4

TABLE G-1 (Cont'd)
MDC AND TOWNS HAVING NO OPTION BUT TO BUY
WATER FROM THE MDC TO MEET 2020 DEMANDS (Cont'd)

Community	Total Safe Yield	Population 1970	Population 2020	2020 Water Demands Average Day	2020 Water Demands Maximum Day	Amount of Water MDC Must Supply Average Day	Amount of Water MDC Must Supply Maximum Day
Southborough	MDC	5,742	17,400	2.0	3.6	2.0	3.6
South Hadley	MDC	17,033	27,195	5.2	8.2	5.2	8.2
Stoneham	MDC	20,565	19,985	6.0	9.3	6.0	9.3
Stoughton	3.1	23,368	41,994	5.6	8.8	2.5	5.7
Stow	MDC	3,909	12,000	1.4	2.5	1.4	2.5
Sudbury	3.7	13,508	45,400	6.1	9.4	2.4	5.7
Swampscott	MDC	13,584	18,158	3.0	5.0	3.0	5.0
Wakefield	1.0	26,200	39,887	10.1	14.7	9.1	13.7
Waltham	MDC	61,108	84,884	32.3	41.4	32.3	41.4
Watertown	MDC	38,853	36,651	7.2	10.9	7.2	10.9
Wellesley	7.7	27,951	32,690	5.6	8.7	0	1.0
Weston	2.1	11,406	27,400	4.4	7.0	2.3	4.9
Westwood	Served by Dedham	12,888	27,591	-	-	-	-
Weymouth	8.2	55,325	61,103	7.6	11.4	0	3.2
Wilbraham	MDC	11,984	21,526	2.7	4.5	2.7	4.5
Winchester	0.7	22,107	23,737	4.5	7.1	3.8	6.4
Winthrop	MDC	20,181	12,136	1.6	2.9	1.6	2.9
Woburn	8.2	37,303	51,600	13.6	19.2	5.4	11.0
Worcester	26.8	175,140	184,535	28.9	37.5	2.1	10.7
TOTALS	134.0	2,677,410	3,237,296	752.9	989.0	621.6	855.0

$0.30 per thousand gallons to $1.75 per thousand gallons of domestic water had not revealed any significant difference in domestic usage in that range. With the recent experience of the oil shortage, and the resultant sharp rise in home heating fuel oil, gasoline and electricity prices, it is not difficult to understand. The less substitutes there are for a product, the more price inelastic that substance becomes. There is no substitute for water, therefore, given a certain standard of living, a certain quantity of water is required. To illustrate this, on a camping trip, a family will use enough water to sustain life, keep clean and launder. This amount of water will probably average between 1 and 2 gallons per person per day. That same family back in their home replete with automatic dish and clothes washers, showers, toilets, lawn sprinklers, and other water using facilities will use an average of approximately 50 gallons per person per day. This additional 48 to 49 gpcd may be considered a "luxury" usage by some, and, therefore, should cost more than is necessary to sustain life. This approach appears unwise for a number of reasons. First, such a policy would tend to widen the difference among the different socio-economic classes. Demographic studies have shown that low income families have more children than middle and high income families. Children directly (bathing) or indirectly (clothes washing) are greater users of water than adults. Therefore, a pricing policy which would effectively curb water use would primarily affect low income families and heighten the differences among the classes, because middle income families would still be able to afford clean clothes and baths, and the high income families would carry on as usual. Secondly, according to the water demand study, the price rise required to curb domestic water usage would raise more revenues than required to pay for the service. Serious questions of equity would have to be resolved prior to such a dramatic price increase. Third, it would not be socially acceptable to raise prices to such a level that only a privileged few could wash cars, water lawns or irrigate gardens. For these reasons, pricing was not further considered in this report as a viable means of reducing domestic water use.

7. Institutional restrictions, eg., summer bans on lawn sprinkling and swimming pool filling, were likewise discarded because while these devices are useful stop-gap measures during an emergency, prolonged usage would lead to an aesthetically unpleasing community with brown lawns and empty swimming pools. This measure was therefore discarded as a technique with potential to modify demands except during emergency conditions.

8. Industrial reuse is seen as a key factor in reducing overall water demands. However, the present cost of pollution abatement has already fostered such technology to be applied wherever possible. It is anticipated that an additional reduction of 3.5 percent of industrial demand could be achieved. A pricing policy here may insure this, as competitive industries tend to search for the least expensive means of production to insure a market.

9. Consumer education and water saving appliances are seen as the two techniques which hold the greatest promise for both the short and long term plans. These two techniques are treated together because unless the consumer is aware of the existence of water saving appliances and devices such as low water use toilets, flow control, and shower heads, there will not be a market for such items. A further description of the potential of this alternative is given later in the section.

TABLE G-2
WASHING MACHINES
PERFORMANCE, CONSUMPTION, AND COST

Model	Performance		Use*	Avg.
	Washing	Overall		Cost
Maytag	Average	Best	34	$ 282
Speed Queen	Below Average	Below Average	34	257
Whirlpool	Above Average	Above Average	35	240
Kenmore	Below Average	Below Average	36	281
Westinghouse	Below Average	Below Average	47	231
Hotpoint	Above Average	Below Average	48	219
Admiral	Average	Average	48	227
Kelvinator	Average	Average	49	245
G. E.	Above Average	Below Average	50	226
Gibson	Average	Average	51	233
Hamilton	Average	Average	51	243
Ward's Signature	Above Average	Average	51	234
West. Auto Citat.	Above Average	Average	51	248
Norge	Above Average	Average	52	219
Frigidaire	Above Average	Above Average	55	244
Blackstone	Average	Below Average	58	266

* Gallons of water @ 40 psi with 8 lb. mixed cotton load and regular fabric cycle using largest fill setting.

WEATHER MODIFICATION

10. As described in Section D, weather modification techniques to increase precipitation patterns and consequently water supply sources are being studied by various governmental agencies. The major thrust of these studies has been in the western states on cloud formations, called orographic clouds, which are caused by the air masses rising over the Rocky Mountains. The results of these studies indicate that man can cause changes in precipitation patterns; however, the magnitude and, in some instances, the direction, of these changes are subject to debate. Computer simulations have been performed on drainage basins with an assumed increase in precipitation which averaged 10 percent per year (although percentage increases in average precipitation rates vary from 0 to 20, a range of 10 to 14 is considered reasonably attainable). This average increase in precipitation caused a 20 to 60 percent increase in stream flow in these simulation attempts. The larger increase in streamflow is due to the fact that precipitation modification techniques cause longer, rather than heavier, periods of precipitation, which, due to the saturation of the ground during the first part of the storm, allows more of the stormwater to reach the stream as overland runoff. This additional water must be held in storage; i.e., reservoirs, for man to derive additional water supply benefits. Also, of particular importance to water supply considerations, is the fact that droughts are not precluded by weather modification techniques because the cloud formations must occur prior to precipitation. The two types of cloud systems, namely convective and cyclonic, which occur in the eastern Massachusetts area however have not enjoyed the success which the orographic modification techniques have experienced.

11. The two remaining cloud systems--convective and cyclonic--are large systems with precipitation efficiencies estimated to be higher than in the orographic system. Convective systems are formed by the natural rising of warm, light air in cold, dense surroundings. Cyclonic systems, which are responsible for most of the cloud and precipitation patterns over North America during the cooler months of the year, are formed when a large body of light, warm air from the south encounters a large body of cold, dense air from the north. The warm air rises over the cold air, forming the cloud system, the boundary between these large air masses is called a "front." Attempts at increasing the precipitation of such systems has been mixed. It appears that redistribution of precipitation occurs, with the target areas experiencing an increase at the expense of other areas within the same system experiencing a

decrease. If it is assumed that the difficulties presently experienced with respect to increasing precipitation in convective and cyclonic systems, the average increase will probably be in the 10 to 14 percent range experienced with the orographic systems. Again, such an increase will be useful for water supply purposes only if it can be stored.

12. As significant as the above planned modifications can be, inadvertent weather modifications by man must also be recognized and accounted for. The great urban centers such as in the northeast, where two-thirds of the nation's population live, presently experience marked climatic differences than the one-third of the nation's population which is rural. Table G-3 lists the climatic changes produced by cities. From the table, it can be seen that man has inadvertently caused approximately the same percentage increase in precipitation that his planned attempts have caused. The interaction between the planned and inadvertent precipitation modifications must be known prior to large scale attempts to increase precipitation in urban areas.

TABLE G-3
CLIMATIC CHANGES PRODUCED BY CITIES *

Parameter	City as compared with rural surroundings
Temperature:	
Annual mean	0.9° to 1.4° F higher.
Winter minimum	2° to 3° F higher.
Cloudiness:	
Clouds	5 to 10 percent more.
Fog, Winter	100 percent more.
Fog, Summer	30 percent more.
Dust Particles	10 times more.
Wind Speed:	
Annual mean	20 to 30 percent lower.
Extreme Gusts	10 to 20 percent lower.
Precipitation	5 to 10 precent more.

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* Precipitation Modification, Lackner, J. D., et al., U. S. National Water Commission, July 1971, NTIS Publication No. PB201534

13. A literature review, by Cooper and Jolly,[1] of the possible environmental effects of weather modification led to the conclusion that gradual changes in plant and animal communities would result. Such alterations could be a significant change from the original condition. The change most likely to be noticed by the general public, however, would be a change in wildlife populations in certain critical localities. The possible synergistic effect of weather modification, air pollution and pesticides is considered to be one of the most important consequences of man's activities which is yet to be assessed.

14. As difficult as the technical and ecological problems of weather modification are, the legal ramifications are at least inter-state, and possibly international in scope. The ability to modify weather could be used to the detriment of some countries as well as, or in conjunction with, a benefit to others. Therefore, due to the scope involved, the legal constraints are seen as formidable.

15. If it becomes possible to overcome the technical, ecological and legal difficulties associated with weather modification and assuming the same increase in streamflow from cyclonic modification as is experienced with orographic modification, the Quabbin-Wachusett Reservoir system could have an increase in safe yield of between 60 and 180 mgd. The latter figure, 180 mgd, with the associated increases in local water resources and the Northfield Mountain and Millers River Basin diversions, would allow the eastern Massachusetts region to meet its estimated 2020 water demand. The 60 mgd figure would require development of an additional 100 mgd ± of water to meet the estimated 2020 demand. However as described earlier formidable barriers exist which must be overcome for weather modification to become feasible. As a result, weather modification is not considered a favorable alternative at this time as an alternative solution to the region's long term need.

WASTEWATER REUSE AS A MUNICIPAL SUPPLY

16. Wastewater has been reused for centuries for water supply. Upstream communities would use the river not only as a source of water supply but also as a vehicle to transport wastes away. Downstream communities would use the river for the same purposes. As rivers became more and more polluted, downstream communities would look to groundwater development, or off-stream upland storage reservoirs for water supply purposes. Today, with the available treatment technology and water demands surpassing the capabilities of groundwater on storage to meet

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[1] Cooper, Charles F. & Jolly, William (May 1969). Ecological Effects of Weather Modification: A Problem Analysis, U. S. Bureau of Reclamation, Michigan, Ann Arbor, Michigan. As quoted by Lackner, J. D., et al., in Precipitation Modified.

these demands, many large communities are once again using the river's waters for water supply and waste transport. Because of the spatial separation in the river of the wastewater discharge pipe and the water intake pipe, this type of reuse is referred to as "indirect". Indirect reuse also applies to recharge of groundwater aquifers by leaching wastewater treatment plant effluent into the soil. This type of reuse provides, after suitable biological treatment, an enriched irrigation water as well as aquifer recharge. The nutrients, namely nitrogen and phosphorus, which could cause eutrophication of surface waters, or, under anaerobic conditions under ground, could cause the formation of hydrogen sulfide, are removed by use of the vegatitive ground cover. Other possibly detrimental elements of the wastewater are filtered out in the top layers of the soil, therefore good quality water augments the groundwater aquifer. Proper utilization of this technique can provide a three fold answer to the question of wastewater discharge: first, a relatively inexpensive (excluding land costs) method of advanced liquid treatment and disposal; second, the irrigation of forested or grass covered areas; and third, augmentation of groundwater aquifers. It is considered that spray irrigation may be used more extensively in the future for individual communities but it is not considered likely to be used as a regional type solution.

17. Direct reuse of wastewater on the other hand has not been practiced extensively. At present, Windhoek, South West Africa, recycles its treated wastewater directly back into its water supply system to make up approximately one-third of the community's water demand. This example however of "direct" reuse of wastewater for municipal water supply is more the exception than the rule. Direct reuse has also been accomplished in the United States on an emergency basis for less than a year in Chanute, Kansas during the severe drought of the mid-1950's. These experiences, plus the effluent quality which can now be obtained with present technology, have prompted many to suggest that reuse is a practical alternative to expansion of an existing water supply source. There are two methods which could be employed for direct reuse. The first would have the wastewater treated and recycled back into the water supply system directly as in the case of Windhoek. The second method, which is discussed more fully later under Dual Water Supply Systems, would have two water systems - one for consumptive uses, and the second for non-consumptive uses.

18. The first method of direct reuse has not to date and may not in the future gain acceptance in the United States because of the need of a fail-safe treatment system for the wastewater, the need to know the long term effects of low level exposure to new chemical compounds, when they

are first used, and, finally, the fact that while most of the public is willing to use treated water for recreational or non-consumptive uses, studies show that better than half of the population is against reusing water for consumptive purposes.

19. The need for a fail safe treatment system for wastewater which will be directly reused is obvious from a health view point. Constant monitoring of the wastes, using sophisticated equipment able to detect heavy metals and other toxins, would have to be performed. Standby emergency treatment units would be required and flow diversion capability would also be required. Although this may be technically feasible, there is a large reluctance on the part of water managers and public health officials to entrust the health of a community to the possibility, no matter how remote, of a mechanical failure. If no other water supply is available, then such a system would be used, as in the case of Windhoek or Chanute. However, the eastern Massachusetts region has the water resources to meet its estimated needs, what is required is wise management of this resource.

20. The second reason that direct reuse will probably not be implemented in this form is a practical consideration of the first reason. As technology advances, literally hundreds of new chemicals are produced daily. The long term, low level exposure effect of these new chemicals is currently unanswered and the possible synergistic effects of these chemicals is also equally unknown, but it could be dangerous. These are the major arguments presented against direct reuse as practiced by Windhoek. Given the framework of assumptions that water supply planners in the Eastern Massachusetts region operate within, namely that there are other fresh water sources available for development, the argument against direct reuse for domestic uses appears valid.

21. In summary, both indirect and direct reuse of wastewater has been practiced at various locations. Direct reuse however has been practiced only where no other alternative sources of supply are available. At present public health authorities do not allow direct reuse for domestic purposes and their apprehensions regarding these techniques suggest even future applications may be limited.

22. The possible use of wastewater as an indirect source through spray irrigation for individual communities may hold promise for the future however. In addition, dual systems which would utilize renovated wastewater for non-consumptive uses has also been advocated of late and a description of this technique is given later.

STRUCTURAL

MERRIMACK RIVER BASIN

23. The water supply needs of a basin may be met by groundwater development, tributary management, or mainstem river management. In general, these developments yield small, medium and large volumes of water respectively. All three types of development have occurred within the Merrimack River Basin. It is anticipated that local groundwater sources will be fully developed by the turn of the century, therefore, tributary and mainstem development only will be discussed further.

24. Within the Massachusetts portion of the basin, the Concord, Little and Powwow Rivers, all tributaries of the Merrimack, are expected to be developed to meet the respective water supply needs of Billerica, Haverhill and Amesbury as discussed under the selected short term plan. The Sudbury River, whose confluence with the Assabet River forms the Concord River, will be discussed separately because of its regional implications. Given the present socio-economic and environmental constraints, no other tributary of the Merrimack within Massachusetts offers opportunities which can be developed to supply the magnitude of water which is required to augment the region's supplies for the long term needs. Mainstem development is, therefore, the only practical consideration for such a large amount of water.

25. Large scale development of the Merrimack River for water supply purposes can be accomplished by two techniques; high flow skimming with water diverted, treated and delivered to the distribution system as required, or continuous withdrawal with flow augmentation provided as needed by upstream reservoir releases. The techniques require the same physical appurtenances - storage, and diversion, treatment and transmission facilities, - differing only in sizing and operational sequence.

26. A simplified example may aid in understanding the principles underlying the two techniques. Assume a community of 60,000 people sits astride a river with an average annual flow of 15 mgd and a flow range during the year between 5 and 50 mgd. Pollution abatement, recreation, fish and wildlife requirements, are 7 mgd of flow in the

river, and the town requires 10 mgd from the river for water supply. Without storage, it is obvious that the river cannot support all needs all the time, in fact, during its low flow period of 5 mgd, it cannot even meet the needs exclusive of water supply. If 7 mgd is established as a control flow, no diversions would be allowed from the river when the flow was 7 mgd or less. Flows above 7 mgd could be utilized in two ways. The first method, or the high flow withdrawal technique, would divert water from the river, treat the water in a large (20 mgd) water treatment plant and deliver the water to the consumer. When flow in the river exceeded 7 mgd in the example, all or a portion of the supply needs would be met from the river. When this river system was in operation, existing storage reservoirs on tributaries would be refilling. When flow in the river was less than 7 mgd, water demands would be met from the existing reservoirs. The second method would be to build a reservoir, upstream from the community and store "excess" river flows (generally the spring floods) into the reservoirs. "Excess" water would be that flow over 17 mgd (7 mgd for water uses & 10 mgd for water supply). A water treatment plant would operate continuously at 10 mgd throughout the year and when river flows were less than 17 mgd, water would be released to the river from the upstream reservoirs, diverted into the treatment plant, treated and distributed to the town.

27. Of course, the above example is an extremely simplified picture of what would actually occur. Questions of riparian rights, land takings, type of treatment plant construction (modular vs. conventional if a large range of flows must be treated), stream flow gaging, control flow establishment, reservoir release timing, possibility of spillage (wastage) at the storage areas, and a host of other related technical, social, political and economical questions must be addressed and solutions found. The following paragraphs detail these two techniques as they relate to development of the Merrimack River for water supply.

HIGH FLOW WITHDRAWALS FROM THE MERRIMACK RIVER MAINSTEM

28. As discussed under the short term alternatives, one of the sites selected for use as a location for a regional or sub-regional water treatment plant was in Tyngsborough. This site has enough land to allow the construction of a large diversion, treatment and pumping facility to serve long term needs by means of the high flow skimming technique, and could be used as the location for both high flow skimming and continuous withdrawal facilities.

29. In general, the high flow skimming process as applied to the Merrimack River would consist of large diversion, treatment, and pumping facilities to make up the additional 210 mgd which the eastern Massachusetts region will require by the year 2020. A large diameter tunnel would connect the Tyngsborough facility with the existing MDC facilities at Norumbega Reservoir and Shaft 9-A at the Malden-Medford line. This tunnel would be constructed at an elevation of -350, Boston City Base, to be compatible with the existing MDC tunnel network, and to cause the minimum amount of surface disruption. A plan of the facilities is shown on Plate 18.

30. The operational sequence would be to meet all or most of the demands of the consumer area by the Merrimack River during the months when streamflow is in excess of that determined to be necessary for other allied water uses. In the absence of other published water requirements, the control flows promulgated for the anadromous fish restoration program and hydroelectric power needs by this study and described in Section C, have been adopted for use. At the same time that the consumer demands would be met by the Merrimack River, the Quabbin and Wachusett Reservoirs would be filling, not only from their own watersheds, but also from the proposed Northfield Mountain and Millers River Basin Water Supply Projects. During low flow periods, when flows are lower than those necessary for allied water resource uses, no diversions would be made from the Merrimack. During such periods, water supply needs would be met by drawing water from the Quabbin and Wachusett Reservoir storage. A major advantage of such a plan is the reduction in upstream storage reservoir requirements which would be necessary in the alternative development (continuous withdrawal) technique under consideration.

31. A disadvantage is the requirement for "overbuilding" which is necessary to deliver a given quantity of water. This is occasioned by the fact that the Merrimack source would not be operating all year round. For example, in order to deliver 200 mgd on an annual basis, if the Merrimack is operating only 6 months out of the year, the facilities must be sized for 400 mgd.

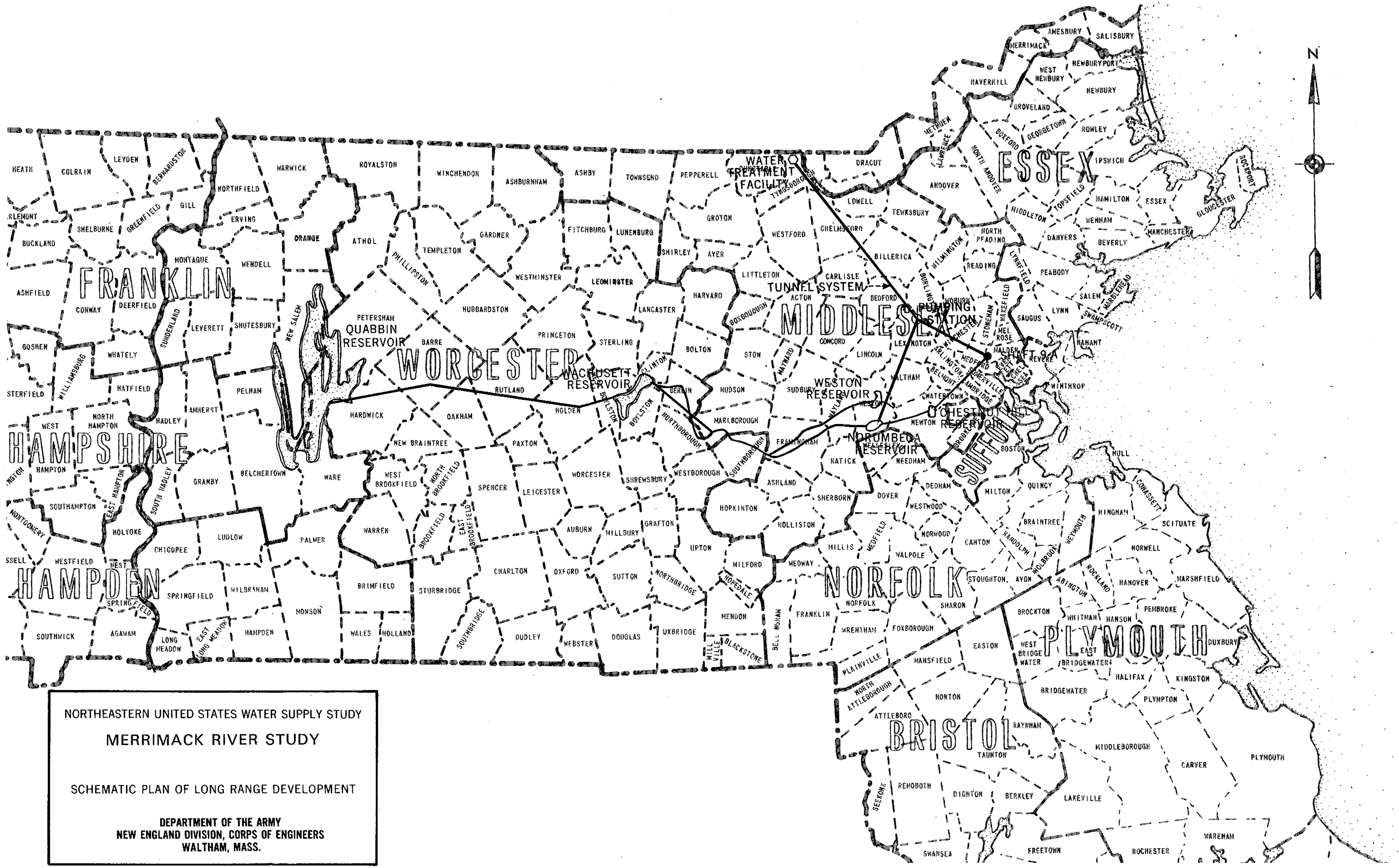
32. However, the high flow skimming technique, which will be more fully discussed later in the section, can meet the water needs of the region, is compatible with allied water uses of the Merrimack River, and can be synchronized with the existing Quabbin-Wachusett storage system, and is therefore considered a viable alternative for the region's long term water supply needs.

CONTINUOUS WITHDRAWALS FROM THE MERRIMACK RIVER MAINSTEM WITH UPSTREAM RESERVOIR STORAGE

33. The operational sequence required to allow continuous withdrawal from the Merrimack, given the same control flows established for the high flow skimming technique, is to divert and treat a constant amount of water for water supply purposes all year round with low flows being augmented by water stored in upstream reservoirs within New Hampshire. The same treatment plant site and tunnel locations shown in Plate 18 would be used as in the high flow skimming technique, however, the sizes for the facilities required would be much smaller under the continuous withdrawal technique. The smaller sizes would reduce the initial construction cost and simplify the treatment plant operation. The operation of the storage sites, regarding the release of flow to the river, would present technical problems which the high flow skimming technique would not. The reservoirs would all be upstream from the treatment plant, and have different river travel times to the treatment plant. Therefore, the flow in the river would have to be anticipated in advance to have the reservoirs release the proper amount of water to the river at the proper time. Such a monitoring network would require, in addition to the requisite number of stream gages, a flow predictive model.

34. In addition to the operational considerations described above, the most serious disadvantage of this technique is that new, upstream reservoir sites would be required. A total of eleven technically feasible reservoir sites have been identified for this purpose in New Hampshire. For the 2020 estimated deficit of 210 mgd, construction of four of these above eleven reservoirs would be required.

35. The continuous withdrawal technique, discussed more fully later, has the advantages of lower construction costs due to the decreased facilities' sizes and the possibility of low flow augmentation in the Merrimack River for water supply and other allied water resource uses. The major disadvantage, and it is a very serious one, is the requirement of upstream storage reservoirs. The concept is valid, however, and the alternative is a viable method of meeting long term regional needs. A more detailed description of this technique therefore is given later in this section.



NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

MERRIMACK RIVER STUDY

SCHEMATIC PLAN OF LONG RANGE DEVELOPMENT

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 18

SUDBURY RIVER REDEVELOPMENT

36. One of the existing water supply sources for the Metropolitan District Commission (MDC) is the Sudbury River Basin located in east central Massachusetts. The system itself, shown on Plate 19, is one of the older components of the supply facilities and its construction predates the establishment of the MDC itself. A historical perspective is included in the following paragraphs.

37. In 1846, the Cochituate Reservoir (previously Long Pond and presently Lake Cochituate) was acquired and developed to meet the City of Boston's water needs through diversion from a sub-basin of the Sudbury River watershed. In 1872 the Sudbury River Act was passed which authorized the diversion of a portion of the Sudbury River itself to the Boston water system. Subsequent to this Act, a series of seven reservoirs were constructed by the Boston water system and later by the Metropolitan water district to develop the watershed. Construction of the last reservoir in the basin was completed in 1898 and a total of 75.2 square miles of drainage area was controlled.

38. In 1947, in response to the availability of supply from Quabbin Reservoir and the higher quality supply from this source, the Massachusetts Legislature transferred control of 4 reservoirs to the Department of Conservation. The reservoirs transferred represented about 50 square miles of drainage area and they were subsequently developed for recreational usage and their water supply use was discontinued.

39. Available water supplies within eastern Massachusetts as described in Section C will be hard pressed to meet future demands. As a result the potential of redeveloping the complete Sudbury River system as a source has received considerable interest of late. A study* to investigate this potential was sponsored by the MDC as part of the Metropolitan Water Supply Development Commission, a special study directed by the Massachusetts Legislature. The purpose of the Sudbury River study "is to develop a comprehensive water resource management program for the watershed, which shall have as its primary objective public water supply utilization consistent with other water resource interests".

40. In the evaluation of the Sudbury River's redevelopment potential all alternatives investigated were assessed for their impact on other existing uses. Included in the existing uses were water requirements for water fowl, fisheries, wetlands, municipal and industrial water supply and wastewater disposal, recreation, evaporation losses, flood protection and low flow augmentation.

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* A study of the Upper Sudbury River Watershed for the Metropolitan District Commission, Commonwealth of Massachusetts prepared by C. E. Maguire, Inc. 1975.

41. Four alternative redevelopment plans were considered. These were; continue operation of the system as at present with the addition of water treatment; redevelop the system with a high flow skimming operation: redevelop the system to maximize water supply with downstream releases limited to the current legislated amount; redevelop the system for recreational purposes.

42. Available water from the first three alternatives ranges from 1.5 to about 51 mgd. Reportedly, each of the alternatives can be implemented "without significantly influencing the environment or other water supplies presently in the watershed". None of the alternatives by itself could provide all of the 210 mgd long range supply needs for the study area but the Sudbury can be viewed as a component of a plan for the long range.

43. Although the report prepared for the MDC is a "Phase One" effort and requires more detailed study the results of this effort indicate that redevelopment of the Sudbury may have merit. As a result, the Sudbury redevelopment is included later as an alternative which could be used to meet a portion of the long range needs within the study area.

CONNECTICUT RIVER BASIN

44. The Connecticut River Basin with a drainage area of 11,265 square miles and an average annual runoff of 12,400 mgd is the largest watershed in New England. Of the total drainage area 114 square miles are in the Province of Quebec, 3059 square miles in New Hampshire, 3937 square miles in Vermont, 2720 square miles in Massachusetts and 1435 square miles in Connecticut. The river rises in the Third Connecticut Lake in the mountainous semi-wilderness region of northern New Hampshire adjacent to the Canadian border. From its headwaters the river follows a general southerly course passing through the states of New Hampshire, Vermont, Massachusetts and Connecticut for about 400 miles to its mouth on Long Island Sound at Saybrook, Connecticut.

45. Water from the basin has long been used for water supply purposes for both in-basin community requirements and through inter basin transfers a large portion of the Boston metropolitan area demands. At present the total developed yield in the basin for public water supply systems is about 420 mgd.

46. The desire to further develop and utilize the basin's resource for water supply purposes becomes apparent when a review is made of a number of engineering reports made since the turn of the century. The

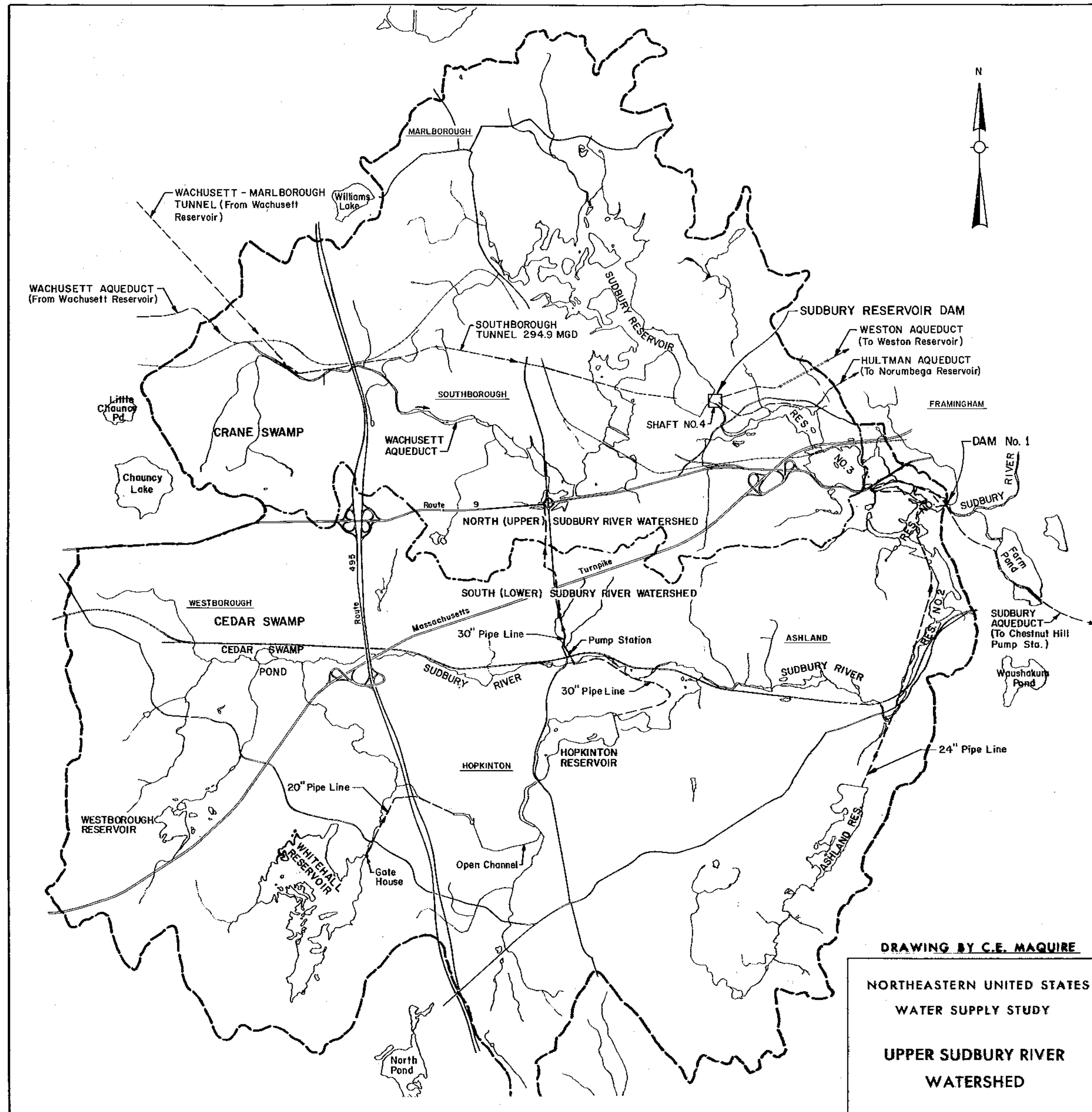
N
MARLBOROUGH
WACHUSETT - MARLBOROUGH TUNNEL (From Wachusett Reservoir)
Williams Lake
WACHUSETT AQUEDUCT (From Wachusett Reservoir)
SUDBURY RESERVOIR
SOUTHBOROUGH TUNNEL 294.9 MGD
SUDBURY RESERVOIR DAM
WESTON AQUEDUCT (To Weston Reservoir)
HULTMAN AQUEDUCT (To Norumbega Reservoir)
SOUTHBOROUGH
FRAMINGHAM
Little Chauncy Pd
CRANE SWAMP
WACHUSETT AQUEDUCT
SHAFT NO. 4
RES. No. 3
DAM No. 1
SUDBURY RIVER
Chauncy Lake
Route 9
NORTH (UPPER) SUDBURY RIVER WATERSHED
Turnpike
Farm Pond
Route 495
SOUTH (LOWER) SUDBURY RIVER WATERSHED
WESTBOROUGH
CEDAR SWAMP
Massachusetts
30" Pipe Line
Pump Station
ASHLAND
RES. No. 2
SUDBURY AQUEDUCT (To Chestnut Hill Pump Sta.)
CEDAR SWAMP POND
SUDBURY RIVER
30" Pipe Line
Waushakum Pond
HOPKINTON
HOPKINTON RESERVOIR
24" Pipe Line
20" Pipe Line
WESTBOROUGH RESERVOIR
WHITEHALL RESERVOIR
Gate House
Open Channel
ASHLAND RES.
North Pond
DRAWING BY C.E. MAQUIRE
NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
UPPER SUDBURY RIVER
WATERSHED

PLATE 19

most pointed example of this desire is illustrated by the Metropolitan District Commission, Boston, (MDC). The MDC in planning for their system's future requirements designed Quabbin Reservoir and the connecting aqueduct to Wachusett Reservoir with capacity adequate to accommodate future developments. Two projects, the Northfield Mountain and Millers River Basin projects as described in Section C were recommended in separate NEWS reports to meet short term needs. Both projects would use the existing Quabbin Reservoir and Quabbin-Wachusett aqueduct capacity and allow for more complete utilization of these facilities.

47. In seeking solutions to the Long Range needs of eastern Massachusetts the Connecticut again was considered as a possible candidate. Any longer range development of the basin would face a myriad of potential impacts including economic, environmental and socio-economic. Even with these possible difficulties however, the large potential of the Connecticut basin's resources mandated an examination of its role in meeting long range needs. As a result development of the Connecticut basin to meet long range supply needs is one of the alternatives examined later in this Section.

PLYMOUTH COUNTY GROUNDWATER

48. A study* of the groundwater resources of Massachusetts was prepared for the Corps of Engineers by the United States Geological Survey. The study was based upon analysis and interpretation of available data and did not include any new exploratory work. The objectives of the study included an estimate of the areal extent and sustained yield of principal aquifer reservoirs which might be used for supplementing municipal and industrial water supplies.

49. A water bearing strata of rock material is called an aquifer. The principal aquifers underlying Massachusetts are of three types: (1) Stratified drift layers of sand and gravel commonly interbedded with some silt and clay (2) Till, a non-stratified, poorly sorted mixture of clay, sand, gravel and boulders; (3) Crystalline metamorphic and igneous bedrock. Till and bedrock aquifers yield small amounts of water, suitable only for domestic supplies. Only those aquifers occurring in stratified drift have the potential capacity to sustain large withdrawals of water.

50. Geologic reports and well logs were studied to determine the distribution and thickness of stratified drift deposits in Massachusetts. Deposits were found about everywhere in the state, but were most extensive in

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* This investigation was conducted as part of the 1969 feasibility study of potential engineering alternatives in the study area prepared by the NEWS study.

the valleys and outwash plains of the east and southeast area.

51. In order to evaluate the aquifers as potential sources of water supply, their water transmitting and storage characteristics were studied. Permeability values, in gpd/sq. ft. were assigned to various lithologies such as gravel, sand and gravel and coarse-medium-fine sand on the basis of the relationship between grain size and permeability. The transmissibility, in gpd/ft. of a lithologic unit was then determined by multiplying the thickness of the unit by its permeability value. Coefficients of transmissibility and storage were also calculated from controlled pumping and drawdown tests at wells sunk in the aquifers.

52. The saturated thickness of the aquifers was mapped where data were available. The thickness was determined by subtracting the elevation of the base of the aquifer from the water table elevation. The saturated thickness of stratified drift, although not necessarily indicative of the presence of permeable zones, has been found by investigators to be a useable favorability guide for a general analysis of the groundwater withdrawal potential. One further indicator of the water content of a groundwater reservoir is the percentage of surface stream flow which is contributed by groundwater. This portion of stream flow is termed base flow or groundwater runoff. Analysis of past records indicates that average annual base flow of a given stream is approximately equal to Q-60 (stream flow equalled or exceeded 60% of the time) in a year of normal climate and equal to Q-70 in a dry year. The Q-70 flow is considered an index to the amount perennially available for consumptive use without depletion of storage.

53. The hydrologic criteria described above were applied to the principal aquifer reservoirs of Massachusetts. In this manner the capability of these reservoirs to serve as alternate sources of water supply could be evaluated. The rates of withdrawal from the aquifers were estimated by assuming the following conditions:

1. No recharge occurs for 200 days in dry years and all the water produced during this period is from groundwater storage;

2. The configurations of the reservoirs were idealized to form elongated rectangles;

3. A system of dewatering wells, 24" in diameter and spaced 2,000 feet apart for 2 mgd yields and 1,000 feet apart for 1 mgd yields, was hypothesized to aid in planning and cost estimates;

4. These wells were assumed to have no drawdown attributed to partial penetration, thinning of the reservoir, nor well losses;

5. Available drawdowns in the wells were limited to two thirds of the saturated thickness for water table conditions and to the top of the producing reservoir for artesian conditions;

6. Current withdrawals of groundwater were included as a part of the estimated withdrawals.

The results were then tabulated by area and rate of withdrawal in mgd/sq. mile and total withdrawal in mgd.

54. The survey of groundwater resources described above indicated that the aquifers in Plymouth County and parts of Cape Cod located to the south of Boston have the capacity to sustain long term, large magnitude withdrawals. The water demand on Cape Cod is increasing at a fast rate; therefore, this area is not considered in this report. The Plymouth County area studied by the USGS comprises 300 square miles and its estimated safe yield is 300 mgd. This estimated rate exceeds the required quantity established as a long range water supply goal of this study. Thus, it was concluded that the Plymouth County area may offer a potential long range alternative source of water supply for eastern Massachusetts.

55. Cost estimates for the necessary resource development were then prepared. Major development items included in these estimates were land acquisition, cost of groundwater development, water treatment facilities, pumping installations and connecting pipelines to the existing distribution system in the metropolitan service area. Development of the wellfields were sized to provide a base load supply source with supply for peak load periods coming from existing surface water storage reservoirs within the service area.

56. In addition to evaluating the engineering aspects of the project, environmental impacts were also assessed. The Plymouth County area is a fast growing area of Massachusetts and water demands within the region are expected to increase in step with this growth. In addition, the Plymouth County area has a large number of recreation ponds and cranberry bogs which could be adversely affected by major groundwater development. Since all water withdrawn and delivered from the aquifers requires pumping, associated energy requirements are high.

57. In summary, investigations of groundwater resources in eastern Massachusetts identified aquifers primarily in Plymouth County which may

have a potential to meet long range needs in the study area. Cost estimates and possible environmental impacts were evaluated to assess use of this alternative source and these are described later.

DESALINATION

58. As discussed earlier in Section D a number of technically feasible methods of desalting are currently available. The present economic as well as environmental costs of desalting however are substantially higher than the other alternatives considered to meet short term needs. As a result desalting was not considered a viable alternative for the satisfying of short range water supply needs within the study area.

59. When desalting is considered for the region's longer range water supply needs, i.e., through 2020, the potential which this technology may hold must be considered. In May 1972 the National Water Commission* prepared a report on desalting, its potential and problem areas. Much of the information contained in the following paragraphs was drawn from that report.

60. In 1971, desalting installations world wide had a total installed capacity of about 205 mgd in 745 plants. This capacity represented an 18 percent annual growth from the 1961 capacity. Distillation is the most extensive process utilized with over 95 percent of the capacity employing this technique. Although many of the plants have relatively small capacities a plant now under construction in Hong Kong will produce 40 mgd when completed.

61. Desalting costs have decreased from early experiences in the 1940's to the present. However, high energy costs of late have apparently reversed the general trend toward lower prices. As noted in Section D the Key West plant has experienced an increase in the price of water from 85¢ per 1000 gallons in 1967 to an average of $3.60 in 1975.

62. Although many forecasts of future desalting costs have been made the assumptions underlying the future estimates differ markedly. As a result comparability is quite difficult and the sensitivity of the assumptions on the estimates is dramatic. For the larger plant size, 50 to 250 mgd, lack of prototype experience could particularly affect the forecasts. Although figures of 20¢ to 29¢ per 1000 gallons are often quoted as achievable by the turn of the century these figures are based on the following conditions which represent difficult criteria at best.

* Desalting by Victor A. Kaclzer prepared for the National Water Commission May 1972.

a. Interest rate is 4.25 percent or less.

b. The plant is dual-purpose (distillation) or accepts raw water with only 900-3000 ppm (membranes).

c. The plant has a capacity of 100 mgd or more.

d. The costs of brine disposal are negligible.

e. No escalation of construction or operating and maintenance costs will occur.

63. As reported in the National Water Commission Report, advancements in desalting technology can be expected in the future but they are likely to be gradual design improvements and not a basic breakthrough. One of the major impediments to future cost reduction is the large quantities of energy used. For example, the most efficient existing distillation plant uses about 100 kwhr per 1,000 gallons. In eastern Massachusetts costs for power from one utility for large industrial users is about 1¢ per kwhr. Energy costs therefore for water from a plant of this efficiency alone would be about $1.00 per 1000 gallons. To this figure must be added the annual debt service on the desalting plant's capital cost as well as operating and maintenance costs. This figure can also be quite sizeable. For example, the 40 mgd plant now under construction in Hong Kong has a construction cost of $92,000,000 or about $2,300,000 per mgd capacity.

64. There are only three ways in which energy costs can be reduced; by reducing the cost of power or steam generation; by use of off peak power and by combining power generation with desalting operations. At present the most potential future possibility for reducing power cost is reported to be use of breeder reactors in nuclear power plants. At one time it was felt that such breeder reactors would be producing a large proportion of the nation's energy requirements by the year 2000. Support for research and development of such breeder reactors recently however has reportedly declined and earlier estimates of their utilization may be overstated.

65. Use of off peak power from peaking generating stations has also been suggested as a means of reducing power costs. In eastern Massachusetts however peaking power is principally supplied by combined cycle turbines and hydroelectric generating stations. The hydroelectric capacity is limited and any draw from that source during off peak periods

would reduce their availability during peak demand times. The turbine generating facilities are gasoline fired and as a result are quite expensive and run only during peak load cycles. Little opportunity exists therefore for use of these installations as an economical power source for desalting operations.

66. Utilization of part of the heat from nuclear or fossil-fueled generating plants probably represents a more dependable method in the future for reducing the net cost of energy in desalting operations than breeder reactors or off peak power facilities. No large dual purpose plants have been constructed within the United States however. As described in Section D a 40 mgd dual purpose distillation plant was proposed for San Louis Obispo and Santa Barbara Counties in California, however the plant was not constructed. Costs for water to be supplied by this plant were estimated to be 73¢ per 1000 gallons but this figure was developed prior to the recent rapid escalation of fuel costs.

67. Since no large dual-purpose plants have been built to date any consideration for development of such plants sized to meet the regions long term needs must face the uncertainty surrounding extrapolation of operating experience from smaller plants. These uncertainties include accuracy of cost estimates, cost allocation, safety, project siting and dual operational responsibilities. None of these problems are reported to be insurmountable but at present there is a lack of prototype experience upon which to draw. The National Water Commission report felt that dual purpose plants of 50 to 100 mgd capacity holds promise for the future but development of a prototype was necessary to answer the uncertainties described above.

68. Aside from the economic constraints which must be overcome if desalting is to become an attractive future alternative there are also environmental problems which accompany this technology. For example, brine disposal can be a serious problem. The volume of brine effluent from a sea water conversion plant is typically between 20 and 70 percent of the total volume treated. From a small 10 mgd plant the volume of effluent would contain about 2,000 tons of salt residue daily. Larger scale plants as would be necessary to meet the regions long range needs of course would have dramatically larger wastes. If discharge can be made to the ocean it is postulated that impacts will be felt primarily on the local ecology but a large amount of work remains in this area.

69. Desalting plants can also affect the environment by discharge of waste heat. A 10 mgd desalter for example will discharge about 65 megawatts of waste heat from a dual purpose plant. Given the difficulties experienced from power plant siting because of such waste heat discharges

it appears desalting plant siting could face some problems particularly in urban areas. In turn these siting problems can have a major impact of economic costs since the further a plant is moved from the water supply need area the higher the costs for necessary transmission and pumping costs.

70. In summary, desalting operations as a means to meet future water supply needs holds promise and they are discussed later in this section. Economic costs and environmental considerations however are major constraints which must be overcome. Since desalination processes are high energy consumers even future use of this technology will be burdened with the associated economic and environmental problems.

IMPORTATION

71. Section E earlier discussed the possibility of importation of water from such distant sources as the Saint Lawrence River basin to provide water supply for the short term needs. As noted the engineering studies conducted indicated that large capital expenditures and operating costs for such an undertaking would be far in excess of developing local resources.

72. The potential of importation as a source for long range needs was also considered. In the case of the long range as was found for short term needs, however, there does not appear to be any advantage to such a large scale development. Economic costs are substantially higher and the complex institutional arrangements necessary for such an undertaking indicate the use of local resources to be a more preferable solution. The importing of water from distant water sources therefore was not considered further in this section.

DUAL WATER SUPPLY SYSTEMS

73. The use of dual water supply systems has been likened to the separation of storm and sanitary wastes now advocated for the older urban centers of the United States. In the case of waste separation, it has been argued that storm water runoff, although a waste, is not a strong waste and therefore does not require the extensive and expensive treatment provided for sanitary wastes. In many instances, storm water retention basins, which provide only settling and chlorination prior to discharge to a river, are all that is required for storm water treatment. The separation allows more capacity in the sanitary sewers for sanitary wastes, reduces the size, and therefore the cost of wastewater treatment plants, and eliminates sewer surcharging and its attendant health problems. In effect, a hierarchy of waste and waste treatment has been established. Recent data suggests however that storm water runoff, particularly during the initial runoff figure, is quite strong and may also require complete waste treatment.

74. Proponents of the use of dual water supply systems in the United States - and they date back at least to John W. Hill, a consulting engineer in Cincinnati, who proposed a dual system for that city in 1894 - argued that the same type of system could work equally well with water supply. Hill's proposal was to filter and disinfect enough of the Ohio River water for drinking and culinary purposes. It would be distributed through a small diameter pipe system. All other domestic, commercial and industrial demands would be met by the existing distribution system, which supplied raw Ohio River water. The cost for implementating this proposal was presented, however, for a number of reasons it was never brought to fruition. Finally in 1907, a rapid sand filtration plant was placed on line and it treated all of the water supplied to the city.

75. The present day proponents of dual systems advocate an approach similar to Hill's i.e., essentially water for drinking, cooking and bathing would be a high quality potable water, while all other domestic uses, such as toilet flushing and lawn sprinkling, would be supplied by a lower quality, non-potable water.

76. The present rationale for the dual system is that the quantity of high quality, protected, unpolluted water for water supply is fixed, and relatively small in comparison to the anticipated future demands. If these demands could be split into two distinct groups, based upon usage, then the high quality water could be protected and meet the future drinking,

cooking and bathing needs while the lower quality water, assumed to be nearby and therefore cheaper to distribute, would be used for all other purposes. With all of the concern being voiced over exposure to chronic, low-level dosages of toxins, this duality of systems, it is argued, would then offer public health protection against this possibility. (It is assumed that the high quality water is stored remote from any possible contamination by such toxins). Public health officials however, have always balked at allowing less than potable water within the home. To offset this concern, advocates of the dual system agree that any water introduced into the home should be biologically safe.*

77. In arid areas of this country, such as the west and southwest, the dual use of hard or highly mineralized water, and softened water has promise. Both would be biologically safe, and, in fact, Catalina Island and other water short islands have had such a system in operation for some time. In addition, a study** by Haney and Hammon showed little annual cost differential between a single system and a dual system if the secondary source were highly mineralized.

78. New England however cannot be classified as arid. Therefore, for dual systems to be practical, given that only biologically safe water will be introduced into the home, they must be shown to be cost effective. Where would the lower quality water come from? If it is from a river like the Merrimack, then the dual system will be much more costly than expansion of a single system due to the "extra" piping network which must be installed. Wastewater reclamation would be the only plausible answer, because it would preclude further development of the rivers. (The study by Haney and Hammon indicated that the potable source need supply only 40 gpcd, therefore, for the approximately 6,500,000 people estimated to be in the study area by the year 2020, total potable supply sources would be called on to furnish 260 mgd. This quantity could be furnished from the Quabbin and Wachusetts reservoirs. The remaining demand of 400 mgd would conceivably be met from reclaimed wastewater delivered through a new dual system.

79. In order to develop a cost estimate for renovating the existing distribution system and retooling of the household plumbing system, data developed by Haney and Hammon in their report were used. Since these estimates were developed for new area construction and not for the retooling of systems in existing urban areas, they are undoubtedly quite low. However, the estimates do provide a bottom figure for the cost of such an endeavor in the study area.

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* Okun, Daniel A. "Alternatives in Water Supply". Journal AWWA, Volume 61

**Haney, Paul D. and Hammon Carl L. "Dual Water Systems." Journal AWWA 57:1073 (Sept. 1965)

80. Cost estimates for refitting older homes and furnishing newer units with dual piping systems was considered to cost $400 per dwelling unit. Based on an estimated need of 2.6 miles of "second pipe" per 1000 customers, about 17,000 miles of new distribution system would also be required. It was estimated this pipe would cost about $125,000 per mile. The advanced waste treatment plant would have a capacity of 400 mgd and was estimated to cost (based on best available information) about $530 million.

81. Overall, the construction cost for the areas dual water supply system was estimated to cost about $1.4 billion, a figure well in excess of other alternatives. In addition to the high capital cost, operating costs could also be expected to be high.

82. Aside from the economic costs involved, this proposal would have widespread socio-economic and environmental impacts. Construction associated with this alternative in a close urban region would be highly disruptive. Noise and air pollution, which accompany the construction, would also be extensive.

83. In summary, this alternative, based on expected health official reaction as well as it's high economic and environmental costs, does not offer an attractive alternative to meet the region's long term needs.

MOST FAVORABLE LONG TERM ALTERNATIVES BASED ON PRESENT KNOWLEDGE

NON-STRUCTURAL

WATER DEMAND MODIFICATION

84. As described earlier in this Section and Section E, the potential of various demand modification techniques was studied extensively as part of this report. Techniques considered included:

a. Water use conservation education programs.

b. Pricing policies.

c. Use of water-saving appliances and manufacturing processes.

d. Institutional restrictions on water use.

e. Leak detection and maintenance programs.

85. Based on present knowledge and the discussion presented earlier in Section E, the most promising of the above methods is considered to be a consumer education program combined with the installation of water saving appliances in new or replacement dwelling units.

86. Consumer education, when combined with use of water saving appliances when these items are installed or replaced, should be economically sound. The greatest savings would occur when water saving toilets and shower heads are installed in lieu of standard model lines. Overall, the installation of water conserving toilets and shower heads in new or replacement dwelling units were estimated to reduce the estimated domestic increase from 1990 to 2020 in the sample survey area by about 7.6 percent. If this figure is applied to the entire estimated 2020 long term regional service area, then the 210 mgd long term (1990-2020) need might be reduced by about a maximum of 30 mgd.

87. In addition to the use of water saving toilets and shower heads in new or replacement homes, there are also a number of other methods which might yield savings in increased water use. These other methods include such items as installation of flow control devices on sinks, modification of washing machines and dishwashing procedures, elimination of food disposers, replacement of commercial and industrial flush type toilets and replacement of grass areas with mulch. Many of these techniques would be difficult to achieve and as a result, unlikely, but if completely implemented, they might save an additional 38 mgd.

88. For the purposes of this study, the consumer education program and installation of water saving toilets and inserts and shower heads are considered to be demand modifications which might reasonably be expected. If implemented fully, these techniques, as noted earlier, could reduce the estimated demand requirements by 30 mgd. As such, demand modification by itself could not meet the entire estimated long term need of the region.

89. However, it could be a very important component of the region's future plans, particularly because other alternatives described later all appear to have reasonably high capital and operating costs associated with them. The demand modification measures considered in this study, on the other hand, have relatively small capital outlays, little, if any, operating expenses and in general would not cause major environmental or socio-economic impacts. For example, the initial additional construction costs for the water saving devices is estimated to be about $23 per dwelling unit. For an average cost of water equal to 60¢ per 1000 gallons, the savings in water bills per year to the consumer would be about $4.00. The additional investment by the homeowner alone would be repaid in about 6 years of use.

90. In summary, the use of demand modification techniques such as consumer education and the installation of water saving toilet and shower head models in new or replacement dwelling units appears to offer promise. If implemented, the modification methods would not by themselves meet the entire long term estimated need, but they would be an important increment in the region's plan.

STRUCTURAL

HIGH FLOW WITHDRAWALS FROM THE MERRIMACK RIVER MAINSTEM

91. High flow skimming is a technique whereby river flows in excess of established minimum or control flows can be diverted, treated and transmitted to consumers. This presupposes that the river is of sufficient quality to be used, and that there exists within the transmission or distribution system sufficient storage to hold all of the diverted river flows which are in excess of the consumers' demands. Rather than assume that these two conditions do exist, extensive studies were undertaken to determine existing conditions and possible changes to these conditions.

92. A report * prepared by the New England Division, Corps of Engineers investigated the possibility of attaining the zero discharge goals of P. L. 92-500 within the Massachusetts portion of the Merrimack River Basin. The report recommended various treatment arrangements for the communities within the Northern Middlesex Area Commission and the Merrimack Valley Planning Commission. The report recognizes that the State-EPA implementation schedule (secondary treatment only) may not, in fact, meet the water quality anticipated under P. L. 92-500. Therefore, various advanced waste treatment alternatives were promulgated for these communities. This preferred plan should provide the basis for any future wastewater management action within the Massachusetts portion of the Merrimack River Basin.

93. Because the lowest classification established for the Merrimack River is Class C, which is acceptable for public water supply after proper treatment and disinfection, and the means of attaining this classification have been outlined in the above referenced report, three further investigations were authorized. These investigations consisted of a water treatment plant study **, which proposed specific unit processes for treating the Merrimack River to acceptable levels for public consumption; and studies 3*4* to determine what environmental effects on the river and its estuary may be caused by diversion of Merrimack River water for water supply purposes.

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* Merrimack Wastewater Management, Key to a Clean River, New England Division, Corps of Engineers, November 1, 1974.

** Water Treatment Plant Study, Merrimack River, Massachusetts. Prepared for the New England Division, Corps of Engineers by Hayden, Harding and Buchanan, Inc., March 1975.

3* An Investigation of Some Environmental Impacts for Possible Diversions of Flow from the Merrimack River. Prepared for the New England Division, Corps of Engineers by Jason M. Cortell and Associates, Inc., April 1975.

4* Ecological Study Merrimack River Estuary - Massachusetts. Prepared for the New England Division, Corps of Engineers by Normandeau Associates, Inc., 1971

WATER TREATMENT PLANT

94. The water treatment plant study investigated various unit processes and combinations thereof to treat the river water to acceptable limits. The study utilized the experience of the existing water treatment plants on the river, an extensive literature review and the judgement gained from previous experience. The following unit processes, shown on Plate 20, were selected on the basis of providing the best possible finished water quality.

a. Intake - Structure allowing access to river with both fixed bar screens and traveling fine screens to remove floating debris from the diverted water. Also inclosed in the structure is the raw water pumping station. Plate 21 illustrates the intake designed for this report. Special emphasis was placed on intake velocities and ability to divert water from different water elevations, to minimize possible diversion effect on roe, fry and adult fish.

b. Chemical Addition - Chemicals perform many functions in a water treatment plant, and their ability to be added at various points in the treatment process increase their efficiency and optimizes plant operation. The chemicals proposed for use in this treatment plant include:

1) Alum - Chosen as the primary coagulent, however, the salt of any trivalent metal could be used. Pilot plant studies would determine which coagulent, and at what dosage, the best results would be obtained. Alum would be added after the raw water pumping station, prior to the rapid mix tank.

2) Lime - Added in various points throughout the plant for pH adjustment.

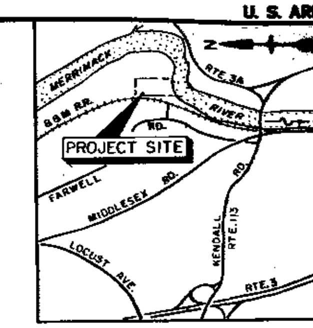
3) Chlorine - Chosen as the primary disinfectant for this plant, it can also be added at various points throughout the plant.

4) Ozone - An unstable oxygen form, it is highly oxidative and therefore used to remove tastes, odors, color, some soluble metals, and to break down certain of the hydrocarbons. Virus deactivation is also accomplished by ozone, therefore it is applied at various stages in the treatment process.

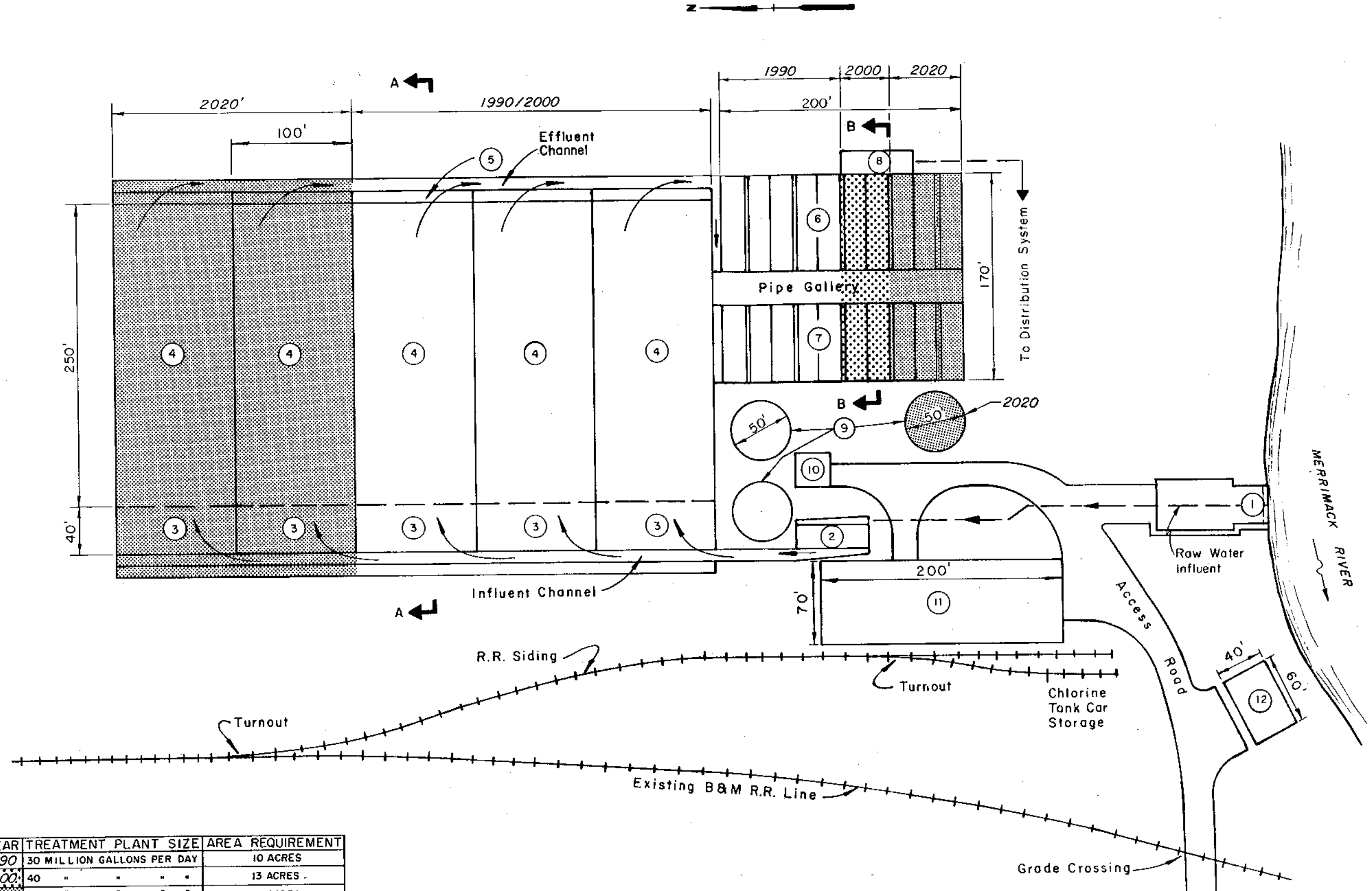
5) Coagulent Aids - Usually polyelectrolytes, are used to reduce the cost of coagulation by reducing the dosage of Alum required to coagulate the suspended matter in the raw water.

6) Potassium Permanganate - An oxidant used to remove tastes, odors, color and soluble iron and manganese during those times of the year when other less expensive oxidants will not perform due to increased concentrations. It is added to the raw water only.

CORPS OF ENGINEERS U. S. ARMY



LOCATION MAP
NO SCALE



YEAR	TREATMENT PLANT SIZE	AREA REQUIREMENT
1990	30 MILLION GALLONS PER DAY	10 ACRES
2000	40 " " "	13 ACRES
2020	62 " " "	18 ACRES

PLAN
SCALE: 1" = 40'

INDEX

1. RAW WATER INTAKE
2. RAPID MIX
3. FLOCCULATION
4. SEDIMENTATION
5. OZONE CONTACT
6. MIXED MEDIA FILTERS
7. CARBON CONTACT
8. HIGH LIFT PUMPS
9. SLUDGE CONCENTRATION TANKS
10. ALUM RECOVERY
11. OPERATIONS & MAINTENANCE BUILDING
12. ADIMINISTRATION BUILDING

SAFETY PAYS

GRAPHIC SCALES
1" = 40' 40' 0 40' 80'

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY M.B. DR. BY L.R.L. CK. BY

SUBMITTED: CHIEF, SECTION
APPROVAL RECOMMENDED: CHIEF, BRANCH
REVIEWED: PROJECT ENGINEER
APPROVAL RECOMMENDED: CHIEF, PROJECT BRANCH

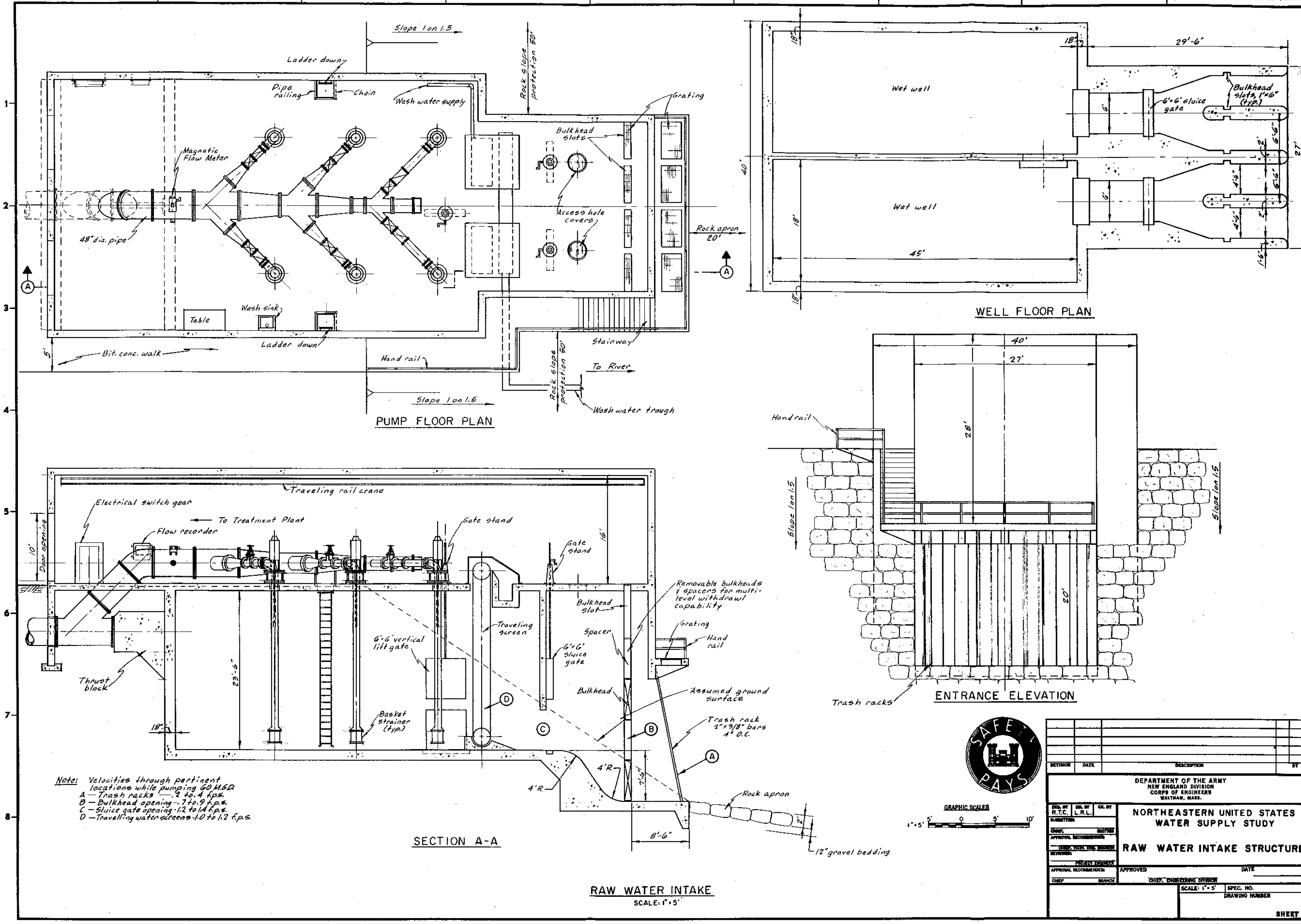
NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

TREATMENT PLANT LAYOUT

APPROVED DATE
CHIEF, ENGINEERING DIVISION
SCALE: 1" = 40' SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 20

CORPS OF ENGINEERS U. S. ARMY



c. Rapid Mixing - After the coagulents are added to the raw water, they must be thoroughly dispersed throughout the water in order to work effectively. This dispersion is accomplished in a tank equipped with small, propeller type paddles which operate at a fairly high speed.

d. Flocculation - After dispersal of the coagulent, the particles must be brought in contact with the suspended matter in the water, so that they will coalesce, become more dense and settle. This contact is provided by a tank with a slowly turning, paddle-wheel type of water agitation.

e. Sedimentation - After dispersal of the coagulent, and the formation of agglomerated particles, called floc, a tank is required for this floc to settle out and be removed from the water. This is accomplished in sedimentation tanks, which are provided with mechanical scrapers to remove the settled particles from the tank.

f. Filtration - Required for removal of the solids remaining after sedimentation. The filter chosen for the plant in this study is a multi-media type which will allow a higher flow rate to be applied, than if other types were used, thereby reducing the construction cost of the filter. The increased cost of the filter media is offset by the reduced construction costs.

g. Granular Carbon Contact - The application of granular carbon to the water will assure a high quality effluent by adsorbing any remaining particulate matter in the water.

95. Raw water quality not only establishes the treatment processes which are required, but also has a direct relationship with the annual operating and maintenance costs. Once the decision is made with respect to the unit processes to be employed, raw water quality dictates the amount of chemicals required, the length of time between filter backwashes, the amount of sludge to be disposed of, and other operating parameters. Based upon the information reported in the Merrimack Wastewater Management report, the annual operation and maintenance costs for various raw water qualities were estimated. These costs are illustrated on Plate 22. Curve "A" on the graph reflects the annual operation and maintenance costs associated with the expected quality of the Merrimack River as a result of the present State-EPA implementation program. Curve "B" on the graph reflects those costs associated with the implementation of advanced wastewater treatment. Curve "C" on the graph reflects those costs associated with water quality which may be expected if no additional waste treatment facilities are installed on the Merrimack Basin. As the graph shows, the variation in annual operation and maintenance costs between the anticipated raw water quality with the EPA-State implementation plan and the raw water quality if no further waste treatment was provided, ranges from

approximately $15,000 per year per mgd plant capacity for a 10 mgd treatment plant to $9,400 per year per mgd plant capacity for a 500 mgd treatment plant. The average savings to be realized by implementation of the State-EPA schedule is $11,700 per year per mgd plant capacity.

96. Should advanced waste treatment become required, additional annual operation and maintenance savings will be realized. This additional savings will vary from $1,600 per year per mgd capacity to $3,400 per year per mgd capacity, with an average savings of $2,300 per year per mgd capacity.

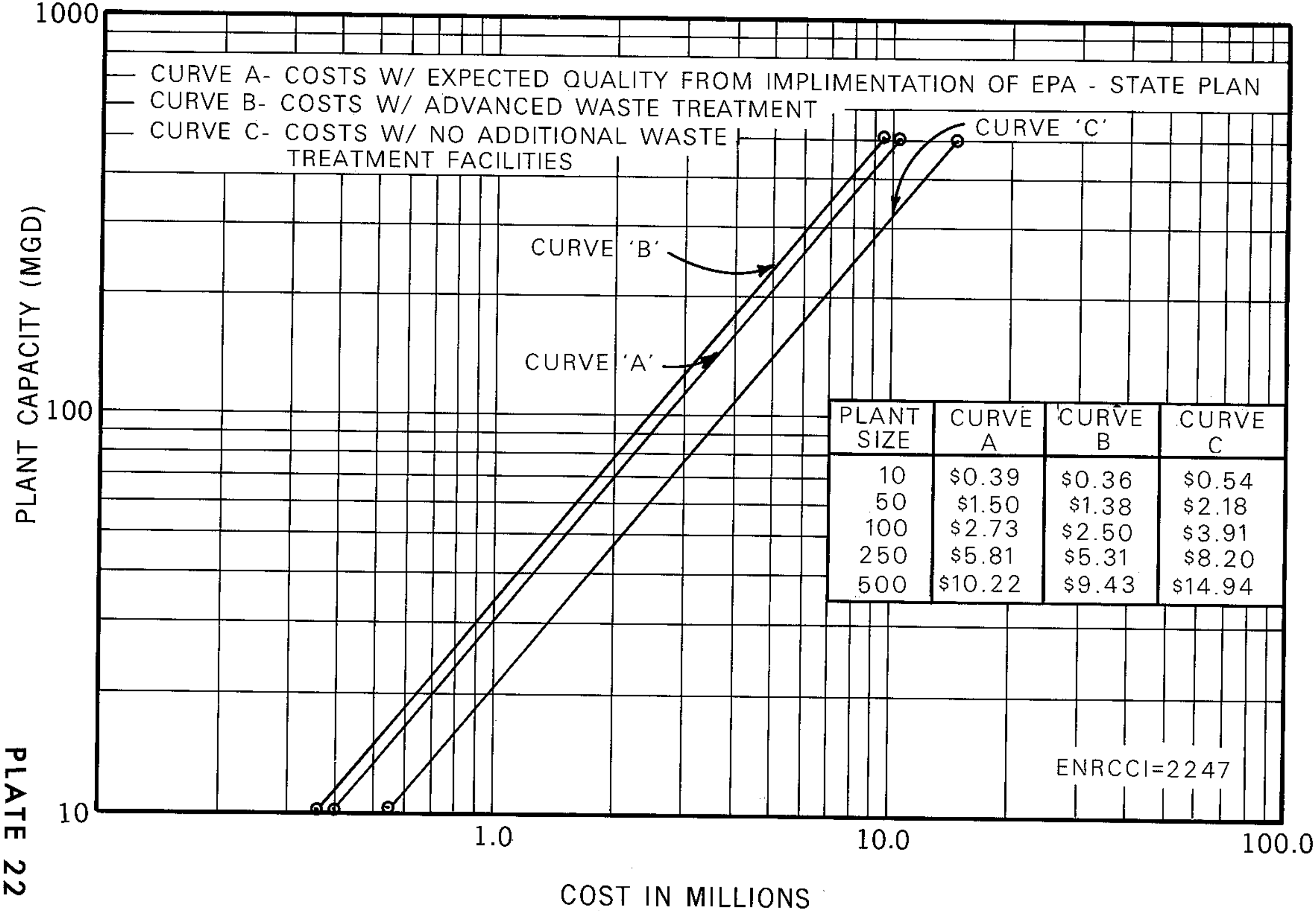
97. For purposes of this study, it was assumed that the EPA-State implementation plan would be in operation. Since construction has already commenced on many of the facilities of this plan the assumption is considered reasonable.

98. Once it was established that the Merrimack River could be used for future water supply purposes; the treatment processes selected, and their dependence upon raw water quality determined, it was necessary to know the amount of water which could be developed by the high flow skimming technique. In order to do this, all other allied water uses and the amounts of water required, had to be determined. The Merrimack River had four major allied water resource uses identified during the course of the study. These four uses were: power generation; water quality maintenance; the anadromous fish restoration program; and, future water supply requirements within the basin.

99. During the course of estimating the in-basin short term water demands, the in-basin long term water supply demands were also calculated. The amount of water estimated to be required for water supply purposes for the in-basin communities within the planning area is 333 mgd of which 70 mgd would be supplied from the Merrimack River. Assuming a consumptive use of 20 percent, only 14 mgd will not be returned to the river. Because this represents an extremely small percentage of other river use requirements, it was assumed that control flows established for the other uses would have sufficient water for water supply purposes for future in basin needs.

100. Flow requirements for the remaining three allied water uses; namely, water quality, existing hydroelectric power facilities and the anadromous fish restoration program were discussed earlier in Section C. As described earlier and shown in the following table, the allied water uses require flow rates which could vary from a low value of 980 cfs for water quality to 6,000 cfs in March and April for the fish restoration program.

EFFECT OF RAW WATER QUALITY ON THE ANNUAL OPERATION AND MAINTENANCE COSTS OF THE WATER TREATMENT PLANT



PLANT SIZE	CURVE A	CURVE B	CURVE C
10	\$0.39	\$0.36	\$0.54
50	\$1.50	\$1.38	\$2.18
100	\$2.73	\$2.50	\$3.91
250	\$5.81	\$5.31	\$8.20
500	\$10.22	\$9.43	\$14.94

PLATE 22

Table G-4. Allied Water Resource Flow Needs * (cfs)
Merrimack River at Lowell, Massachusetts

Month	Water Quality	Existing Hydroelectric Power	Anadromous Fish Restoration Program	Average Monthly Flow
January	980	3,500	2,000	5,000
February	980	3,500	2,000	6,200
March	980	3,500	6,000	10,400
April	980	3,500	6,000	17,000
May	980	3,500	4,000	9,600
June	980	3,500	4,000	5,000
July	980	3,500	3,500	3,000
August	980	3,500	3,500	2,400
September	980	3,500	3,500	2,200
October	980	3,500	3,500	3,000
November	980	3,500	3,500	3,000
December	980	3,500	2,000	5,400

* Note: figures shown are flow rates considered satisfactory for purposes shown. The values presented, however, are not additive. For example, a flow rate of 6,000 cfs in March would satisfy not only the anadromous fish program requirements but those also for water quality and hydroelectric power.

101. As illustrated in Table G-4, the lowest flow constraint on potential development is related to meeting improved water quality. The highest flow values are those required for the existing hydroelectric facilities and the proposed anadromous fish restoration program. It should be noted that in some months (July through November) the historical average monthly flow has been lower than some of the calculated flow needs. The implication of this shortfall is that late summer and fall migrations of anadromous fish are not likely under average runoff conditions in the Merrimack. In addition, hydroelectric power production during this natural low flow period is curtailed during average flow years.

102. For purposes of this report, a combination of the existing power and anadromous fish restoration program needs were used in sizing the needed Merrimack needs. Thus adopted control flows for the high flow withdrawal project would be 3,500 cfs in the months of January, February and July through December; 6,000 cfs during March and April; and 4,000 cfs during May and June. The adoption of these control flow rates strongly influence the economics of the project and the implications of their selection is described later in "Necessary Future Actions".

103. Possible environmental impacts of the project on the Merrimack River using the flow rates described above was also investigated. Impacts considered included the effect of the diversion on wetlands, flooding, navigation, wildlife refuges, riverside land use and commercial and recreational usage of the river. Overall it was determined that the impacts should not be significant on these related environmental resources.

104. A third study* dealt with the possible effects that divisions may have on the river's estuary. A range of diversion rates from 100 to 2,000 cfs were tested in this study. The study specifically addressed salinity changes, solids deposition and current pattern changes within the Merrimack River estuary. The aquatic biota was also investigated, and an assessment of changes resulting from diversions of various magnitudes was attempted. The following conclusions were drawn from the study:

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* Ecological Study Merrimack River Estuary - Massachusetts. Prepared for the New England Division, Corps of Engineers by Normandeau Associates, Inc. 1971

Table G-5
Possible Effects of Diversion on the Merrimack River Estuary

DIVERSION RATE	EFFECT
100 cfs	No significant ecological effects are predicted for any month of the year.
300 cfs	It is unlikely that any significant ecological effects would occur during any month of the year.
500 cfs - 800 cfs	No significant ecological effects are predicted for the months of January, February, March, April, May, June, November or December. However, during the months of July, August, September, and October, the prediction is made that effects are possible, but there is insufficient data to speculate on their magnitude.
1,100 to 2,000 cfs	July, August, September, and October - Significant ecological effects are probable.
	January, February, June, November and December - effects are possible but cannot be predicted.
	March, April, and May - No effects are expected.

105. As shown in Table G-5, the high flow withdrawal rate of 597 cfs falls within the diversion rate tested from 500-800 cfs. No significant ecological effects are predicted within the estuary for withdrawals of this magnitude during the months of January through June; November and December. There could be, however, possible impacts if diversions were made during the period July through October.

106. Referring to Table G-5, it should be noted that the adopted control flows used in this study would preclude diversions on the average during the period (July-October) when possible effects might occur in the estuary. Since the diversions would not be operative during the critical low flow period, no effect is predicted in the estuary itself from the high flow project.

107. The results of all the studies indicate that the Merrimack River can be developed for water supply purposes by the high flow skimming technique. To insure compatability among these water use and other allied water resource uses, diligent monitoring of stream flows, water quality parameters, and the success of the anadromous fish restoration program would be required. Although this project is under consideration for long term implementation, which negates identifying specific problems which may arise, there are general environmental and socio-economic considerations which are linked to water supply development, deep rock tunnel construction and inter basin water transfer, all of which pertain to this project and in general, to all of the other structural alternatives described later. In the later discussions of alternatives, special considerations applicable to the particular project are also described but it must be recognized that any large scale construction project would have associated impacts similar to those given for the high flow withdrawal plan.

108. The socio-economic and environmental effects which were surfaced during the course of this study, along with those effects which are required to be addressed by Section 122 of P. L. 91-611 are listed below:

A. Noise: Construction activity at the proposed water treatment plant site in Tyngsborough, and at each of the proposed tunnel access shaft locations, would generate noise typical of this type of construction, ie., forming, concrete work, steel erection, and other job-related activities. The noise generated by this activity will be site specific, that is, it will affect only those in proximity to the construction site. Deep rock tunnels generate quantities of rock spoil. The disposal of this spoil requires sufficient land and trucking from the tunnel access shaft to the applicable spoil area. This truck travel could be along residential areas (depending upon spoil area location or tunnel access shaft locations) which would substantially increase the level of noise along those routes during construction.

B. Displacement of People: Other than eleven camps and one farm which would be taken in the proposed water treatment plant site in Tyngsborough, no other displacement of people is anticipated if this project is implemented.

C. Aesthetic Values: The proposed water treatment plant and tunnel access shafts would have little impact, if any following construction on the aesthetics of the surrounding areas. Treatment plants can be designed to blend in with their environment. Tunnel access shafts could also be designed this way. (If the shafts were to be used for maintenance purposes, a structure of some design would be required for entrance to the shaft proper; otherwise, the shaft would be plugged after construction and grassed over).

D. Housing: A project of this magnitude would be expected to have an impact on demands for rentals and residences. Deep rock tunneling is a specialized skill which would require the hiring, and subsequent move to the area, of a firm specifically established for this work. Many of these firms are located in the mid west and west. The deep rock tunneling effort would require a construction time of approximately 7 years, therefore, the demand for single family housing units as well as rentals would be expected to increase. Because of the length of tunnels, however, it is impossible to determine where this increase would be felt, or its magnitude. If it is assumed to be spread over all the communities within communting distance, the net increase would be minimal.

E. Transportation: The deep rock tunnel requires hauling the excavated rock to previously determined spoil areas. The location of these spoil areas has not been determined, however, they would normally be located within an economically feasible distance from the tunnel access shafts. This additional trucking could have a disruptive effect upon local traffic patterns.

F. Education Opportunities: As in the case of housing, an overall increase in the population of school aged children would be expected because of the influx of extra regional workers to construct the deep rock tunnels. However, the probable dispersion of these children throughout the area would not bring any space or financial hardships to any one educational system within the study area.

G. Community Cohesion: One of the reasons for selecting the deep rock tunnel method of construction was to minimize the potential community disruption which a cut and cover construction method would certainly have on the area. Some land will be required for tunnel access shafts and spoil areas, and the location of these, especially the latter, will certainly generate heated debate. This debate will not be anywhere near as intense as if the entire 36 miles of proposed tunnel were replaced by a cut and cover construction method. Thus, although the potential placement of shafts and spoil areas will require a great deal of study and public involvement, the construction method selected was an attempt to minimize community disruption.

H. Community Growth: One of the requirements for growth identified in the discussion of the short term plan was the availability of a potable water supply of sufficient quantity. This alternative would supply that water by augmenting the existing sources of the region's largest water retailer. Therefore, community and regional development would not be hindered by the lack of a water supply.

I. Institutional Relationships: Because of the question of riparian rights and inter basin transfer of an interstate water, certain institutional relationships would have to be developed. Mutual agreement on the use of the Merrimack River may have to be reached between New Hampshire and Massachusetts. The rights of the Lowell and Lawrence based companies for water generation of electricity would have to be clearly defined, and any losses which may occur to those companies would have to be properly compensated for. Because of the complexity of these issues, further study and recommendations would be required prior to implementation of the development of the Merrimack River.

J. Health: The primary concern of any water utility is delivering water in as pure a state as the present technology allows. Even with the increased river water quality which is anticipated after implementing the State-EPA program, the water treatment facility proposed was designed to treat a range of water quality. Therefore, no adverse health effects are anticipated by this project, its intent, in fact, is to improve the health and well being of the region's population.

K. Municipal Tax Revenues: Historically Massachusetts has compensated municipalities which have lost taxable properties due to land takings required for regional water supply purposes. It can be assumed therefore, that land required for this project would be compensated for. Because water supply development, especially of this magnitude, would remove one growth constraint, it can be anticipated that the municipal tax bases within the region would grow at least in proportion to the population, because industrial and commercial growth would not be constrained. An increase in local taxes or water rates, however, would probably be necessary to pay for this development, unless extra regional funding sources were used.

L. Property Values: Property values within the region would tend to maintain their present position at least. Supply of sufficient water for home gardening and landscaping could, in some areas, raise the property values of houses not now able to implement such undertakings due to lack of water during the growing season.

M. Land Use: Land use changes in Tyngsborough at the proposed water treatment plant site would occur as described under the Regional alternative of the short term plan. Overall, approximately 100 acres of land would change usage - 85 acres of which is presently farmed with the remaining acreage devoted to riverside camps. Along the proposed tunnel route, a total of four access shafts would be required, as well as 29 acres of land for excavated tunnel rock disposal. The total of approximately 150 acres of land required for this project is insignificant when compared to the area of the region, however, the town of Tyngsborough alone has two-thirds of the total acreage required, and the selection of the shaft and spoil areas will require detailed analysis. The quantity of land use changes is relatively small, however it will be lost to the communities forever, and therefore all ramifications should be known and mitigated against if at all possible.

N. Public Facilities: Expansion of community water distribution systems would be allowed because of the sufficiency of the source. No other effect on existing public facilities is anticipated.

O. Public Services: Other than the possibility of extending community water services, no change in existing public services is anticipated. The project will, of course, allow the continuence of all public facilities and services which require water - fire fighting, hospitals, swimming and wading pools, and other public activities.

P. Regional Growth: As previously indicated under the Community Development discussion, regional growth would not be constrained by implementation of this plan, it would, in fact, be encouraged by the removal of water supply as a possible growth inhibition.

Q. Employment: Although some of the estimated 330 man work force the deep rock tunnels require would originate from out of the region, the work force required for construction of the water treatment plant would be mostly local hires. For a 385 mgd water treatment plant alone this would represent a total of almost $24 million in salaries paid over the life of the project to the local work force. Due to the future time period in which this will occur, it is impossible to assess the impact this project would have on the unemployment rate, or on the secondary effects which reduction in unemployment has. However, at present Massachusetts has an unemployment rate of about 14 percent and any construction activity would be expected to help this situation.

R. Business and Industrial Activity: As previously indicated, the implementation of this water supply plan will, in the least, remove one growth constraint which faces certain industries. During the construction phase of the project, there would be an increased demand upon construction material suppliers, and a marginal increase in demand on commercial establishments such as eating and drinking establishments.

S. Displacement of Farms: The proposed water treatment facility will remove 85 acres of land from corn and pasture land production in Tyngsborough. This represents a total of 9 percent of the present agricultural and open space land of Tyngsborough. No other effects on active farmlands are anticipated by the implementation of this project.

T. Man Made Resources: No direct effect is anticipated on any man made resource as a result of this project.

U. Natural Resources: The plan involves usage of a natural resource - the Merrimack River - to provide a source of water supply. Four different investigations were conducted as part of this report on the various aspects of this resource use. As previously described, allied water resource uses were identified and their compatibility with the proposed water supply development studied. Various sets of control flows have been promulgated for use in this report, and are considered compatible with other uses of the river.

V. Air: Increased particulate matter, especially dust, will be produced by the trucks hauling the rock spoil from the tunnel access shafts to the spoil areas along the tunnel route during the tunnel construction. In Tyngsborough near the proposed treatment plant site, increased dust levels will also be noticed during construction of the treatment facility. No increase in air pollutants is anticipated during the course of the project life.

W. Water: During construction of the proposed water treatment plant's intake structure, an increase in Merrimack River turbidity levels downstream from the construction site is anticipated. No other adverse effects on the River during construction is anticipated. The possible detrimental effects to the river which may occur during the operation of this proposed plan center around the reduced flows which would be experienced. The selection of the control flows will naturally have the greatest influence on the river. However, control flow establishment is a two sided issue. If the control flows are high, diversions can only be made during a fairly short time period of the year, and the facilities must be over designed to divert, treat and transmit the equivalent of the approximately 210 mgd deficit which is forecast. If the control flows are low, then the diversion, treatment and transmission facilities can be smaller, (because they will operate for a longer period throughout the year), and therefore less expensive, however the anadromous fish restoration program will suffer, and the use of the river for power purposes will be curtailed. The establishment of control flows for development of the Merrimack River as a water supply source will be one of the most difficult and controversial issues of this technique.

X. Land: Disposal of the proposed water treatment plant sludges, which would undoubtedly be treated at one of the proposed wastewater treatment facilities, will require burial at a sanitary landfill. Although this is the purpose of a landfill, the addition of such a large amount of bill material, with vacuum filtration - approximately 1 to 2 tons of solids per million gallons of treated water - would have a significant impact on the life expectancy of the landfill area. Excavated tunnel rock would also have to be placed in spoil areas. It has been estimated that approximately 29 acres of land will be required for this purpose.

DESIGN AND OPERATION OF THE HIGH FLOW SKIMMING TECHNIQUE

109. The design and operation of the facilities required for implementation of the high flow skimming technique depends, in large measure, on the control flows selected for the river. In this study, the higher level flows necessary for power generation and the anadromous fish restoration program were selected and sizing of the necessary facilities were based on that level.

110. Facilities required for development of an annual yield of 210 mgd include a 385 mgd water treatment facility as well as about 36 miles of 12 foot diameter tunnel and an appropriately sized pumping station. Operation would be for approximately 6 1/2 months during an average year. Chemical storage problems would arise due to their finite shelf lives and because chemical costs are a significant portion of the overall annual operation costs, these costs could rise significantly due to wastage.

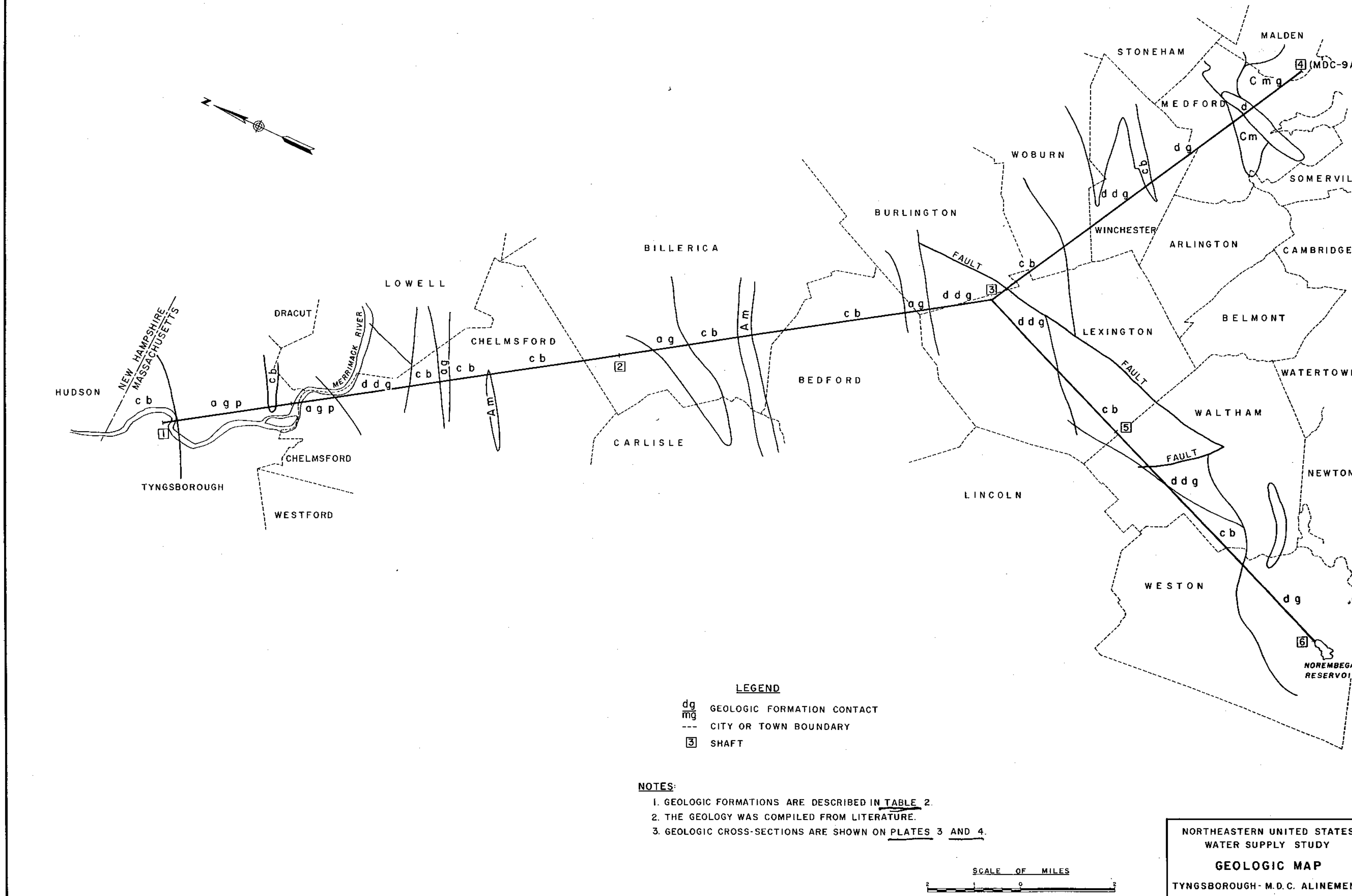
111. The tentative location for the proposed water treatment facility is in Tyngsborough, Massachusetts on the west side of the Merrimack River. The facilities to be located on this approximately 100 acre site include an intake structure, similar in design to that shown on Plate 21; a water plant and all appurtenant facilities similar in design to that shown on Plate 20; and the entrance shaft to the deep rock tunnel. Plate 23 shows the configuration of the proposed tunnel system. It travels south from Tyngsborough through Chelmsford, Billerica, Bedford, Burlington and Lexington, where it assumes a Y configuration with one leg passing through Woburn, Winchester and Medford to the existing Shaft 9-A in Malden, and the other leg continuing through Lexington and Waltham to the Weston and Norumbega Reservoirs in Weston. The interconnection between the Weston and Norumbega Reservoirs will allow more efficient use of the capacity of the existing Weston Aqueduct. All tunnels will be at elevation -350 Boston City Base to coincide with the existing MDC tunnel elevations. In addition to the tunnel headworks, three additional access shafts are required en route.

112. For the use of the control flows established for the power needs and the anadromous fish restoration program, a 385 mgd water treatment facility, 12 foot diameter tunnels and a pumping station within the tunnels able to pump approximately 425 mgd of water against a total dynamic head of approximately 275 feet would be needed. The costs of these facilities are listed below.

113. In general, the operation of the system would begin in late autumn when the river flows surpassed the control flows. At this time, the Quabbin-Wachusett Reservoir system, as well as the distribution reservoirs, are normally at their annual lowest levels of storage and require filling. A proposed addition to the existing aqueduct system described later would raise the capacity of the pressure aqueduct to 600 mgd and the distribution reservoirs would have to be able to meet the maximum month conditions without benefit of refill from the Quabbin-Wachusett system. With the proposed Northfield Mountain and Millers River diversions working in concert with the Merrimack River diversion, Quabbin and Wachusett will fill while meeting a portion of the system demands. The remaining demands and the filling of the distribution storage will be accomplished by the Merrimack River diversion.

114. The present transmission capability of the MDC system is constrained by the pressure aqueduct from Shaft C to Shaft 1, and the lack of a connection between the Weston and Norumbega Reservoirs. For the purposes of this study, the addition of the pressure aqueduct between Shaft C and Shaft 1 has been included as a cost of the project. This construction will increase that capacity to approximately 600 mgd at normal operational elevations.

115. If during the winter months, Quabbin and Wachusett Reservoirs are filled to capacity and start to spill, that is waste water, the Merrimack diversion would be shut down. Because there is no treatment or pumping of water from Quabbin into Boston, this is a much less "expensive" water than the Merrimack would be. If no spilling occurred, then the Merrimack diversion would continue to operate until the control flows and river flows coincided. Diversion from the Merrimack River would then cease, and all demands would be met from Quabbin-Wachusett and distribution storage. With the "Y" portion of the tunnel able to carry flows from Weston Reservoir to Norumbega, or back to Shaft 9-A in Malden, the City Tunnel will not be a constraint against meeting demands. The water would simply come in from the north instead of the west by the loop formed by the "Y". (The stem of the "Y" which goes to the treatment plant in Tyngsborough would be closed during this operation). Additional lift may be required at the existing Chestnut Hill pumping station to meet the anticipated Boston area and southern area water demands.



NOTES:
1. GEOLOGIC FORMATIONS ARE DESCRIBED IN TABLE 2.
2. THE GEOLOGY WAS COMPILED FROM LITERATURE.
3. GEOLOGIC CROSS-SECTIONS ARE SHOWN ON PLATES 3 AND 4.

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

GEOLOGIC MAP

TYNGSBOROUGH - M.D.C. ALINEMENT

PLATE 23

116. Total project first costs for this alternative are estimated to be about $495 million. Annual costs including Interest and Amortization, Operation and Maintenance and Major Replacement are estimated to total about $41 million. Costs of water from the high flow withdrawal alternative delivered to the existing regional primary transmission system would be about $0. 54 per 1, 000 gallons. Cost estimates for the projects' principal components are shown in the following table.

CONTINUOUS WITHDRAWALS FROM THE MERRIMACK RIVER MAINSTEM

117. The second method of developing the Merrimack River mainstem as a water supply source would withdraw water on a continuous basis. Water withdrawn would be treated in a water treatment plant similiar to that described earlier for the high flow operation. Finished water would be delivered to consumers via transmission aqueducts. The location of the facilities are as shown on Plate 18.

118. The primary difference between the continuous operation and that considered for high flow periods is that the continuous method would deliver water on a year round basis. During low flow periods in the river when natural river flow is less than the control flows described earlier, make up water would be released from new upstream reservoirs. The water released from the reservoirs would be that amount desired for diversion and control flows less the quantity provided by the river flow itself.

119. The major advantage of this alternative method of operation is that the major new facilities, i.e., water treatment plant, pumping stations, and connecting aqueduct, need only be sized for the quantity desired. The water treatment plant would be 210 mgd versus the 385 mgd plant required for the high flow withdrawal technique while tunnel sizing from the plant to the service area is also considerably reduced from that necessary in the high flow plan. In the continuous withdrawal plan, the tunnel to the "Y" connection at Shaft 9A and Norumbega Reservoir would be about 36 miles and 10 feet in diameter. The high flow plan required a 12 foot diameter aqueduct from the treatment plant to the beginning of the "Y". Pumping facilities of course would also be less for the continuous operation than the high flow method. The possible environmental and socio economic impacts described for the high flow operation would also apply generally to the continuous method of operation. The only significant difference which would be expected would be at Tyngsborough where land requirements for the plant itself would be about 50 acres for the 210 mgd plant versus 80 acres for the larger high flow plant and spoil areas for the smaller

Table G-6
Merrimack River Mainstem High Flow Withdrawal

Project First Cost

Component			Cost
Water Treatment Plant (385 mgd capacity)			$ 125,000,000
Tunnel Connection to Existing System (12 foot diameter, mole and conventional excavation)			
Segment 1	(Tyngsborough to Chelmsford)	5.2 miles	20,118,000
Segment 2	(Chelmsford to Carlisle)	4.5 miles	10,735,000
Segment 3	(Carlisle to Bedford)	4.0 miles	11,300,000
Segment 4	(Bedford to Lexington)	4.0 miles	13,794,000
Segment 5	(Lexington to Winchester)	4.3 miles	17,867,000
Segment 6	(Winchester to Malden)	4.0 miles	15,308,000
Segment 7	(Lexington to Lexington/Waltham)	4.0 miles	14,820,000
Segment 8	(Lexington/Waltham to Waltham)	2.9 miles	10,134,000
Segment 9	(Waltham to Weston)	2.9 miles	9,424,000
All Shafts			6,276,000
Pressure Aqueduct Shaft C - Shaft 1		1.8 miles	8,919,000
Pumping Stations			25,000,000
Real Estate			2,000,000
Contingencies			58,139,000
Engineering & Design			42,209,000
Supervision & Administration			27,558,000
Total Project First Cost			$ 418,600,000
Interest During Construction			76,700,000
Investment			$495,300,000

Table G-6 (Cont'd)

Annual Costs

Component	Cost
Interest and Amortization	$ 31,972,000
Operation and Maintenance	8,944,000
Major Replacement	409,000
Total Annual Charges	$ 41,325,000
Cost per 1000 gallons	$ 0.54

10 foot diameter tunnel would require about 7 acres less than the high flow plan.

UPSTREAM RESERVOIRS

120. Offsetting the reductions in environmental and socio economic impacts in the continuous withdrawal plan are the impacts associated with the necessary upstream reservoirs. During the course of this study, over 100 potential flow augmentation sites were investigated. In the screening of these sites the following criteria was used:

a. All sites should have a capacity of 15,000 acre feet or greater.

b. Reject those sites which state or local officials have expressed opposition in writing to the project.

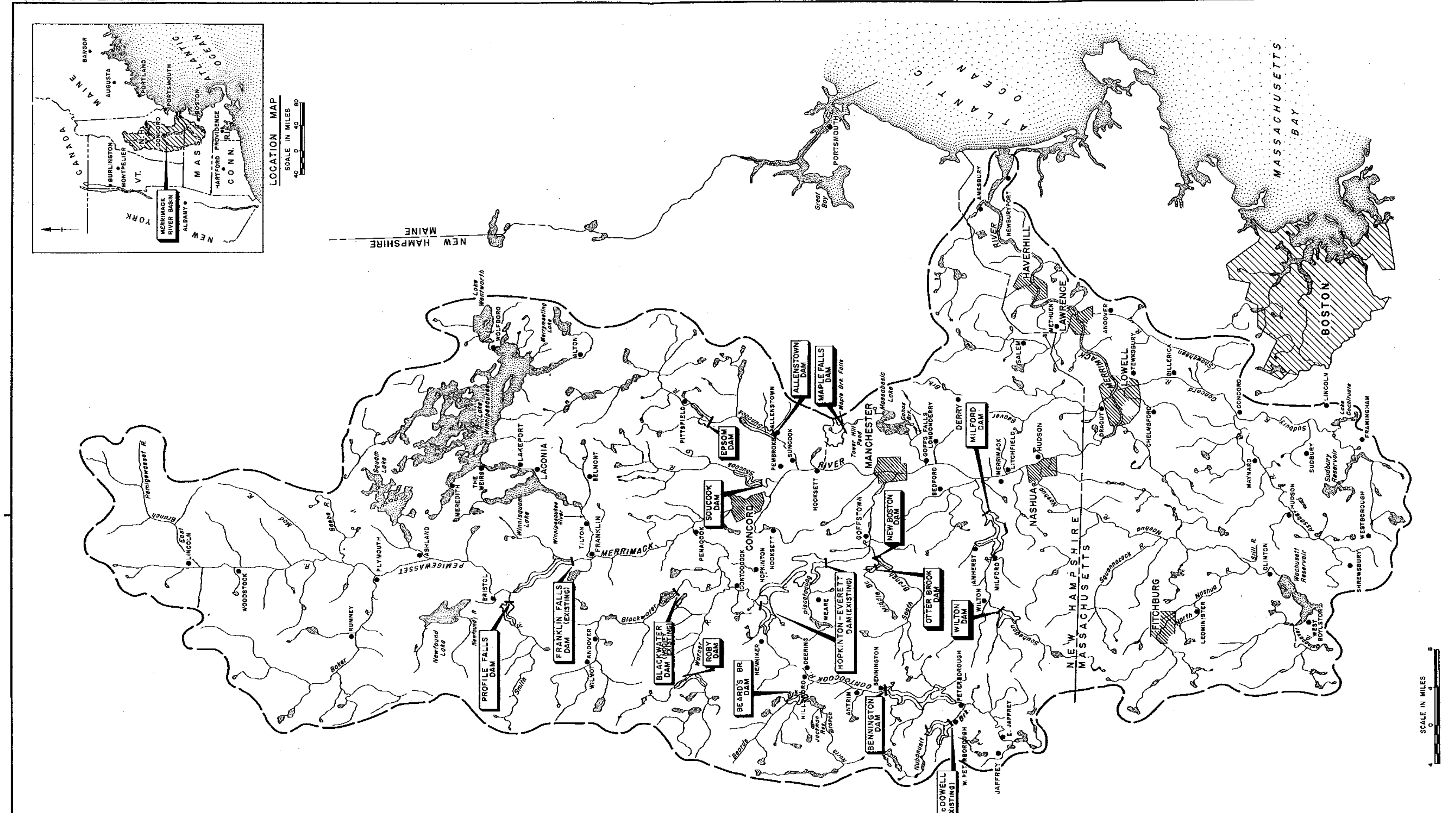
c. Reject those sites where major real estate highway or other facilities relocation would be necessary.

d. Reject all mainstem sites.

121. Utilizing this criteria, 11 sites, shown on Plate 24, were selected for more detailed study. These were:

Profile Falls (on Smith River)
Bennington (on Contoocook River)
Roby (on Warner River)
Beards Brook (on Beards Brook and North Branch Contoocook)
Soucook (on Soucook River)
Epsom (on Soucook River)
Allenstown (on Suncook River)
New Boston (on Piscataquog River)
Otter Brook (on Otter Brook)
Wilton (on Souhegan River)
Milford (on Souhegan River)

122. Pertinent data on each of the sites are given in Table G-7. As shown in the table, storage considered at the various sites ranged from 16,000 to 78,500 acre feet. Drainage areas for the sites varied from 38 to 246 square miles on nine tributary rivers of the Merrimack River. Construction costs for the projects were estimated from a low of $8.6 million for the Otter Brook Reservoir to $40.1 million for the Bennington Reservoir.



REVISION	DATE	DESCRIPTION	BY

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
BOSTON, MASS.

DR. BY | TR. BY | CK. BY

FLOW AUGMENTATION RESERVOIR SITES
MERRIMACK RIVER BASIN

CHIEF P. & R. SECTION
SUBMITTED BY:
CHIEF, PLANS & RPT'S BRANCH
APPROVED:
CHIEF ENGINEERING DIV.
APPROVED
COL. C.E. DIVISION ENGINEER
DATE
SCALE
DRAWING NUMBER
SHEET OF

Table G-7
Possible Upstream Storage Reservoir Sites

Reservoir	River	Drainage Area (miles)	Storage Considered (acre-ft)	Costs ($ million)	Cost per Acre-Foot
Profile Falls	Smith River	86	60,000	$ 28.255	$470
Bennington	Contoocook River	186	60,000	40.140	669
Roby	Warner River	88	36,000	15.451	429
Beards Brook	Beards Brook and North Branch Contoocook	120	34,500	16.618	482
Soucook	Soucook River	89	27,600	10.281	372
Epsom	Soucook River	157	67,000	31.140	465
Allenstown	Suncook River	246	78,500	39.824	507
New Boston	South Branch of Piscataquog River	103	43,900	21.634	493
Otter Brook	Otter Brook	38	16,000	8.644	540
Wilton	Souhegan River	68	41,700	19.862	476
Milford	Souhegan River	165	41,400	33.928	820

123. Each site was analyzed for its potential as a primarily flow augmentation facility, and also it's possible multi purpose use. Possible multi purpose applications at each site investigated included flood control, fish and wildlife, recreation, power and water quality enhancement. Engineers and biologists from the Corps of Engineers and the U. S. Fish and Wildlife Service visited each site and evaluated each of the sites. A description of each of the sites and their major features is included in the following paragraphs.

PROFILE FALLS

124. The Profile Falls site is located on the Smith River approximately 4500 feet upstream of the falls which are at the Route 3 A bridge. Development of this reservoir would be primarily for water supply flow augmentation and flood control.

125. Construction costs for this site are average with respect to other sites investigated, with the majority of the cost attributed to the large amounts of earth work required. Relocation associated with the reservoir development include 4 miles of state highway, about 40 homes, 2 large farms, a school and a local cemetary.

126. Based on an earlier Corps of Engineers study in 1972, development of the reservoir could provide about $350,000 [1] in annual flood control benefits. Based on an analysis by the Fish and Wildlife Service, development of the reservoir, however, could cause significant fish and wildlife losses as the Smith River reportedly supports an excellent trout fishery and has excellent potential as a salmon smelt rearing area.

127. Development of Profile Falls could offer potential recreation benefits. In an earlier (1972) Corps of Engineers study, New Hampshire state officials expressed some interest in the development of a state park in conjunction with the reservoir.

128. Water quality and downstream power benefits could also be expected. Detailed power studies were not conducted as part of the water supply investigations but 4 power installations (see Plate 12, #'s 15, 16, 17 and 23) with an installed capacity of 27,800 kw would benefit from increased usable flow. From a water quality perspective, about 85 miles of river reaches would receive augmented flow during operation.

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1 1972 field investigation and price levels.

129. Overall, the Profile Falls site offers a large capacity potential for both water supply flow augmentation and flood control. The Smith River is used for trout fishing and this use reportedly would be adversely affected. Downstream users including power facilities and water quality would benefit from the project due to the increased river flow between the reservoir and water supply intake works.

BENNINGTON

130. The Bennington dam site is located on the Contoocook River just south of the town of Bennington, New Hampshire. Three towns, Greenfield, Hancock and Peterborough would be affected by the reservoir. The reservoir considered would be a dual purpose site incorporating recreation and fish and wildlife with the water supply flow augmentation function.

131. Construction costs for the site are average with respect to the other sites considered. Relocation of over 90 structures including a restaurant, motel, automobile showroom and 15 new homes, however, would be required.

132. With respect to multi purpose development, the Bennington site would offer little additional flood control benefits, as the site is located downstream and upstream from two existing flood control reservoirs. The site reportedly could be developed to enhance fish and wildlife and recreation needs within the region. In addition, the site would benefit four downstream power plants (#'s 15-18) with installed capacity of 25,700 kw and increase river flow in about 106 miles of downstream river reaches.

133. The site had been investigated in the past for its potential as a flood control reservoir, other dam sites however were developed. In general, construction of a dam and reservoir at the Bennington site would cause a large disruption in an area which is apparently undergoing a revitalization. Socio economic impacts could therefore be expected to be large. Overall, the Bennington dam site therefore is one of the least desirable of the sites investigated.

ROBY

134. The Roby dam site is located on the Warner River and the towns of Warner and Sutton, New Hampshire about 1500 feet downstream from the confluence of the Lane River with the Warner River. The site could be developed as a multi-purpose facility with benefits accruing to water supply flow augmentation, flood control, fish and wildlife and recreation.

135. Construction costs associated with Roby are low in relation to other sites. Relocation associated with the reservoir could affect about 21 homes, 3 camps, 2 mobile homes and 11 barns. Most of the land is forested and the area in general is not too heavily built up.

136. From a flood control perspective, the Warner River is one of the remaining uncontrolled tributaries to the Merrimack River. If flood control were included at the site, initial estimates indicate that significant annual benefits would accrue.

137. Both fish and wildlife and recreation activities can also be incorporated at the site, however, drawdown restrictions associated with those activities would limit the use of the facility for water supply purposes.

138. Because Roby is a relatively small storage site, the incorporation of all other potential uses may not be achievable because of the necessary conflict over available storage. The site is, from an economic view, a reasonably priced facility without any apparent major deterrents to its development. In general then, the Roby site is considered to be one of the more favorable sites investigated.

BEARDS BROOK

139. The Beards Brook dam site is located on Beards Brook in the town of Hillsboro, New Hampshire. The facility would be a single purpose water supply augmentation storage reservoir with a diversion channel from the North Branch Contoocook River to increase the effective drainage area and yield.

140. Construction costs for the project are moderately high, however, associated relocations are generally low. Relocations involve short sections of local roads and the construction of a bridge for Route 202 over the spillway. In addition, 12 houses, 2 camps, and 3 barns would be within the reservoirs flow line. Two large summer camps may also be affected but this determination would require detailed studies. In general, the area is sparsely settled and development of the reservoir could be accomplished without major disruptions.

141. Other uses of the reservoir site are limited primarily because of existing flood control reservoirs and the topography at the site. Downstream benefits would accure to water quality and five power installations with a capacity of 25,300 kw. Overall, however, the primary beneficiary of the Beards Brook reservoir would be the water supply function. Even lacking the potential for other water uses, however, this site is considered favorable compared to other available sites.

SOUCOOK

143. This site is located on the Soucook River about 4 miles southeast of Concord, New Hampshire. Investigations indicate the site could be developed as a dual purpose reservoir providing water supply augmentation storage and flood control. In addition, the reservoir offers an opportunity to provide storage for local water supply use.

144. The construction costs for this site are the lowest of all locations studied. Relocation caused by the reservoir would affect a short section of town road and 4 houses and 11 mobile homes. Even though the reservoir site is located close to the City of Concord, New Hampshire, it is relatively undeveloped at present.

145. Flood peaks in the Soucook River are considerably modified by natural valley storage. However, its modified and retarded flood discharges tend to synchronize with flood peaks on the mainstem Merrimack. Flood control benefits attributable to the site would be primarily from the reduction of the Soucook's construction to mainstem Merrimack flood flows. With regard to fish and wildlife and recreation uses, however, the site is not well suited.

146. One factor which must be recognized in the evaluation of the Soucook site is the location of Concord's public water supply wells within the reservoir area. In view of the high quality of the well supply and the availability of other more suitable local reservoir sites, Concord would probably oppose any development of the Soucook site. As a result, even with its low economic costs, the Soucook site does not appear to be favorable for development.

EPSOM

147. The Epsom dam site is located on the Suncook River, three miles downstream from the village of Pittsfield, New Hampshire in the towns of Epsom and Chichester. The site could be developed as a multi-purpose reservoir with water supply flow augmentation, flood control, fish and wildlife enhancement and recreation.

148. Construction costs for the project are moderately high and real estate costs, although not a large fraction of the total cost, are nevertheless substantial. Thirty eight houses, 1 snowmobile shop, 1 store, 1 mobile home park and 19 barns would have to be purchased. In addition, State Route 28, some short sections of town road and a section of electric transmission line would have to be relocated.

149. The Epsom site is upstream of the Allenstown site (described later) and if constructed, would offer significant downstream flood control benefits. The site also has a good potential for extensive recreation development particularly when viewed as an adjunct to the nearby Bear Brook State Park. In addition, a potential for enhancing fish and wildlife in downstream river reaches also exists.

150. Water quality and downstream power benefits from development of Epsom would be less than many of the other sites investigated because of its location. Downstream river reaches total about 6 miles on the Suncook and 40 miles on the main stem Merrimack. Three power plants with a capacity totalling 17,600 kw would benefit from increased river flow.

151. In general, the Epsom site with its large drainage area and storage capacity offers a good opportunity for development and is considered one of the more favorable sites considered.

ALLENSTOWN

152. The Allenstown site was a site which received detailed consideration as a flood control reservoir in a 1972 Corps of Engineers flood control study. The limitations set by the State of New Hampshire on the flood control operation would prevent the use of this site for water supply flow augmentation. Essentially, the state requires a constant pool with a storage capacity of only 4000 acre feet. This of course would not be compatible with a flow augmentation reservoir operation. Allenstown, therefore, was not considered as favorable for development.

NEW BOSTON - OTTER BROOK

153. The Otter Brook site located on Otter Brook 1000 feet upstream from its confluence with the South Branch of the Piscataquog River is actually part of the New Boston site located just downstream of this confluence. Since both sites are integrally connected, they are discussed together here.

154. Construction costs for both sites would be moderately high. Road relocations for both sites are not major but a recently constructed 56 acre recreation pond (Daniel Pond) is a major consideration. To date, 27 camps with recreation hall, beach facilities, and comfort stations have been built. More development can be expected in the near future. In addition to the Daniel Pond development, Otter Brook would require the taking of 14 houses, a store, 4 mobile homes and 6 barns. With the New Boston reservoir, an additional taking of 27 houses, 3 mobile homes, a farm, store and 4 barns would also be required.

155. Opportunities within both reservoir sites for fish and wildlife enhancement and recreation are not considered favorable. Since the flow in the Piscataquog is already controlled by the existing Hopkinton-Everett flood control reservoir, neither reservoir would provide any significant flood control benefits. Downstream power and water quality benefits are also minimal since there is only one downstream generator of 1000 kw capacity and only 30 miles of the Merrimack would be subject to increased flow.

156. Overall, it appears that the two sites have little potential except as water supply augmentation storage reservoirs. Relocation and real estate takings would be high and opposition could be expected. Neither the New Boston or Otter Brook sites are considered favorable relative to other available sites.

WILTON

157. The Wilton dam site is located on the Souhegan River about one mile downstream from the confluence of Blood Brook with the Souhegan and about two miles southwest of Wilton, New Hampshire. The site could be developed with project purposes of water supply augmentation, fish and wildlife and recreation.

158. Construction cost estimates for this project are moderately high. The reservoir area is reported to be relatively undeveloped. However, 5.5 miles of state highways will have to be relocated. In addition, the reservoir area has 23 houses, 7 mobile homes, 8 barns and a small concrete factory.

159. Flood control potential are limited at the site, despite the relatively large storage capacity at the site. This is because; the confluence of the Souhegan with the Merrimack is downstream of some major damage centers; the Souhegan River flood crests on the rising side of the Merrimack flood crest and Soil Conservation Service (SCS) dams on the river's tributaries have significantly reduced local flood damages.

160. Opportunities for fish and wildlife enhancement and recreation are also limited. Although some benefits may be realized, operation of the flow augmentation operation would prevent full realization of these benefits.

161. Downstream power facilities and water quality would also receive minor benefits. Only one 600 kw installation at Wilton would benefit and 22 miles of Merrimack and 16 miles of the Souhegan would have increased low flows.

162. Overall, the Wilton site has no outstanding characteristics and therefore it is average with respect to the other sites available. It does provide a fair amount of storage capability and could provide water supply flow augmentation.

MILFORD

163. The Milford dam site is located on the Souhegan River in the town of Merrimack, New Hampshire about 4.6 miles above its confluence with the Merrimack River. The site could be developed as a dual purpose water supply flow augmentation and recreation reservoir.

164. Construction costs for this reservoir are the highest of all sites investigated. Relocations invclve large sections of State Routes 101 and 122 as well as the relocation of railroad tracks located adjacent to the reservoir. The large amount of land (3300 acres) required to be taken in this prime suburb of Manchester and over 200 homes, a country club, 3 lumber companies and 4 working farms make this site the most undesirable from a relocation viewpoint.

165. Although recreational development can be incorporated into the project, development of the reservoir would inundate over 9 miles of trout stream. Flood control benefits for the site would be minimal because of similar reasons to those described for the Wilton site and minor downstream power and water quality benefits can be expected. In general, this site is one, if not the least desirable, for development.

UPSTREAM STORAGE REQUIREMENTS FOR THE CONTINUOUS WITHDRAWAL ALTERNATIVE

166. For purposes of this study, upstream storage requirements for water supply make up water was determined based on an analysis of the critical drought of the sixties. The relationship between yield and upstream storage requirements is graphically illustrated on Plate 25. As shown on the plate, the control flow utilized in the operation of the project influences the quantity of necessary storage. For example, if a 210 mgd yield is required from the river and the control flow is based on calculated anadromous fish restoration flow and reported existing hydroelectric flow needs then the necessary storage is about 185,000 acre feet. If on the other hand water quality flow needs were the sole basis for the control flows then necessary storage for a 210 mgd yield would be about 45,000 acre feet.

AUGMENTATION STORAGE DURING SIXTIES DROUGHT
OF RECORD VERSUS WATER SUPPLY YIELD

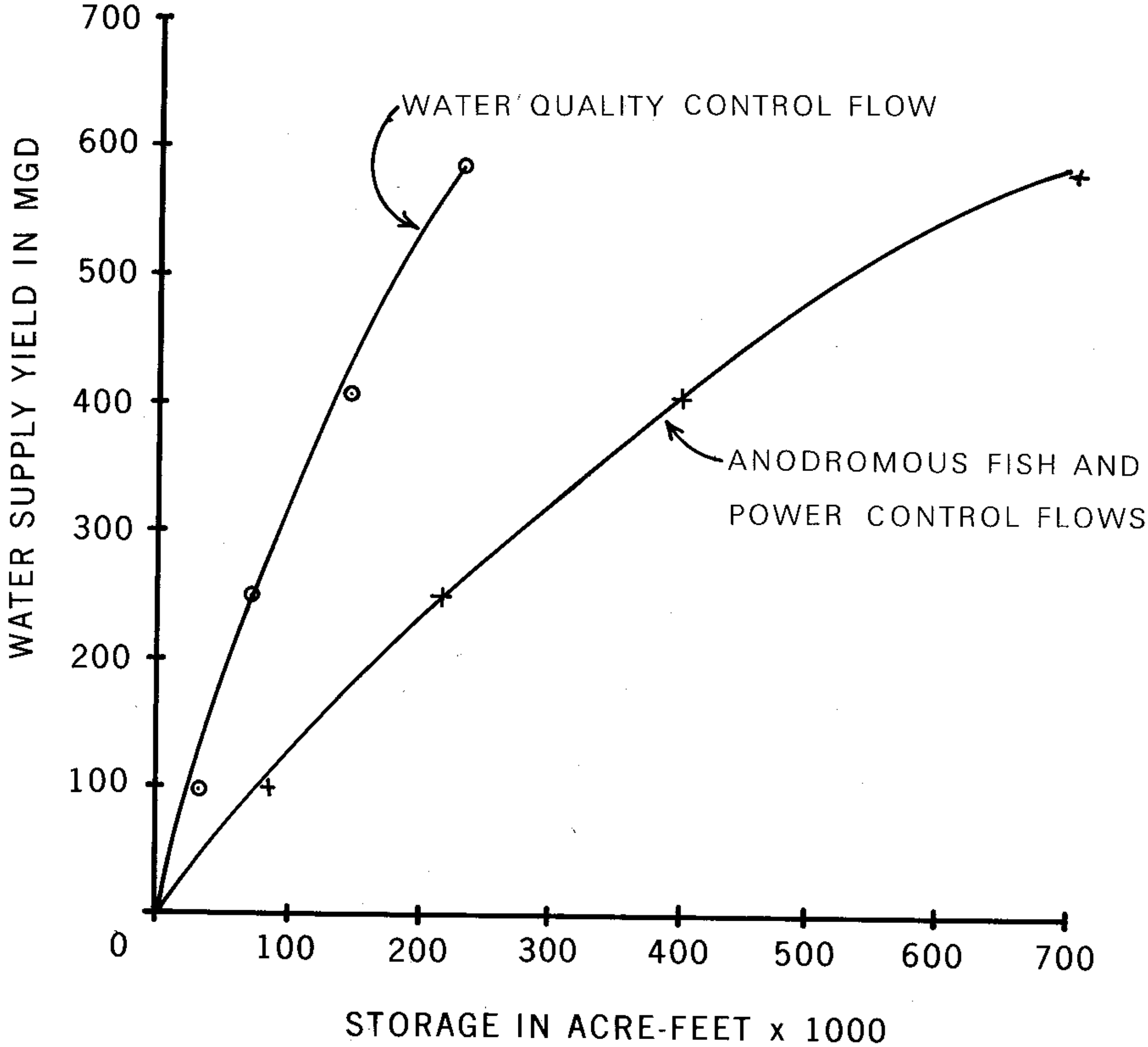


PLATE 25

167. The control flows formulated for the anadromous fish restoration program and the reported existing hydroelectric plants were used in estimating needed storage. In order to develop the 210 mgd of additional yield for the long term, about 185,000 acre feet of new storage capacity would be needed. Based on economic, environmental and socio-economic criteria, the most favorable reservoirs which could furnish this storage would be Profile Falls, Roby, Beards Brook and Epsom.

COST ESTIMATES

168. In order to develop the Merrimack River on a continuous basis to supply an additional 210 mgd, the necessary facilities would be; four new upstream reservoirs; a 210 mgd water treatment plant with appurtenant structures; about 36 miles of 10 foot diameter tunnel connecting to the existing regional (MDC) aqueduct system at Shaft 9A and Norumbega Reservoir; and a pumping installation to deliver the water from the Merrimack River to the hydraulic grade needed for connection to the regional system.

169. Total project first costs for this alternative are estimated to be about $385 million. Annual costs including Interest and Amortization, Operation and Maintenance and Major Replacement are estimated to be about $37 million. Costs of water from this alternative delivered to the existing regional primary transmission system would be about $0.48 per 1,000 gallons. Cost estimates for the project and components are shown in Table G-8.

Table G-8
Merrimack River Mainstem Continuous Withdrawal

Project First Cost

Component			Cost
Water Treatment Plant (210 mgd capacity)			$ 72,000,000
Tunnel Connection to Existing System (10 foot diameter, mole and conventional excavation)			
Segment 1	(Tyngsborough to Chelmsford)	5.2 miles	16,987,000
Segment 2	(Chelmsford to Carlisle)	4.5 miles	9,763,000
Segment 3	(Carlisle to Bedford)	4.0 miles	9,413,000
Segment 4	(Bedford to Lexington)	4.0 miles	11,331,000
Segment 5	(Lexington to Winchester)	4.3 miles	14,655,000
Segment 6	(Winchester to Malden)	4.0 miles	12,691,000
Segment 7	(Lexington to Lexington/Waltham)	4.0 miles	12,591,000
Segment 8	(Lexington/Waltham to Waltham)	2.9 miles	8,171,000
Segment 9	(Waltham to Weston)	2.9 miles	7,883,000
All Shafts			5,727,000
Pressure Aqueduct Shaft C-Shaft 1			8,919,000
Pumping Stations			11,700,000
Upstream Reservoirs [1]			
Profile Falls			28,255,000
Roby			15,451,000
Epsom			31,140,000
Beards Brook			16,618,000
Real Estate			2,000,000
Sub-Total			$ 295,295,000

Table G-8 (Cont'd)

Contingencies	$ 40,766,000
Engineering and Design	29,596,000
Supervision and Administration	19,323,000
Total Project First Cost	$ 384,980,000
Interest During Construction	56,700,000
Investment	$ 441,680,000

Annual Charges

Interest and Amortization	$ 28,510,000
Operation & Maintenance [1]	8,076,000
Major Replacement	249,000
Total Annual Charges	$ 36,835,000

Cost per 1,000 Gallons	$ 0.48

[1] Reservoir Costs Include Real Estate, Contingencies, Engineering & Design and Supervision and Administration.

SUDBURY RIVER REDEVELOPMENT

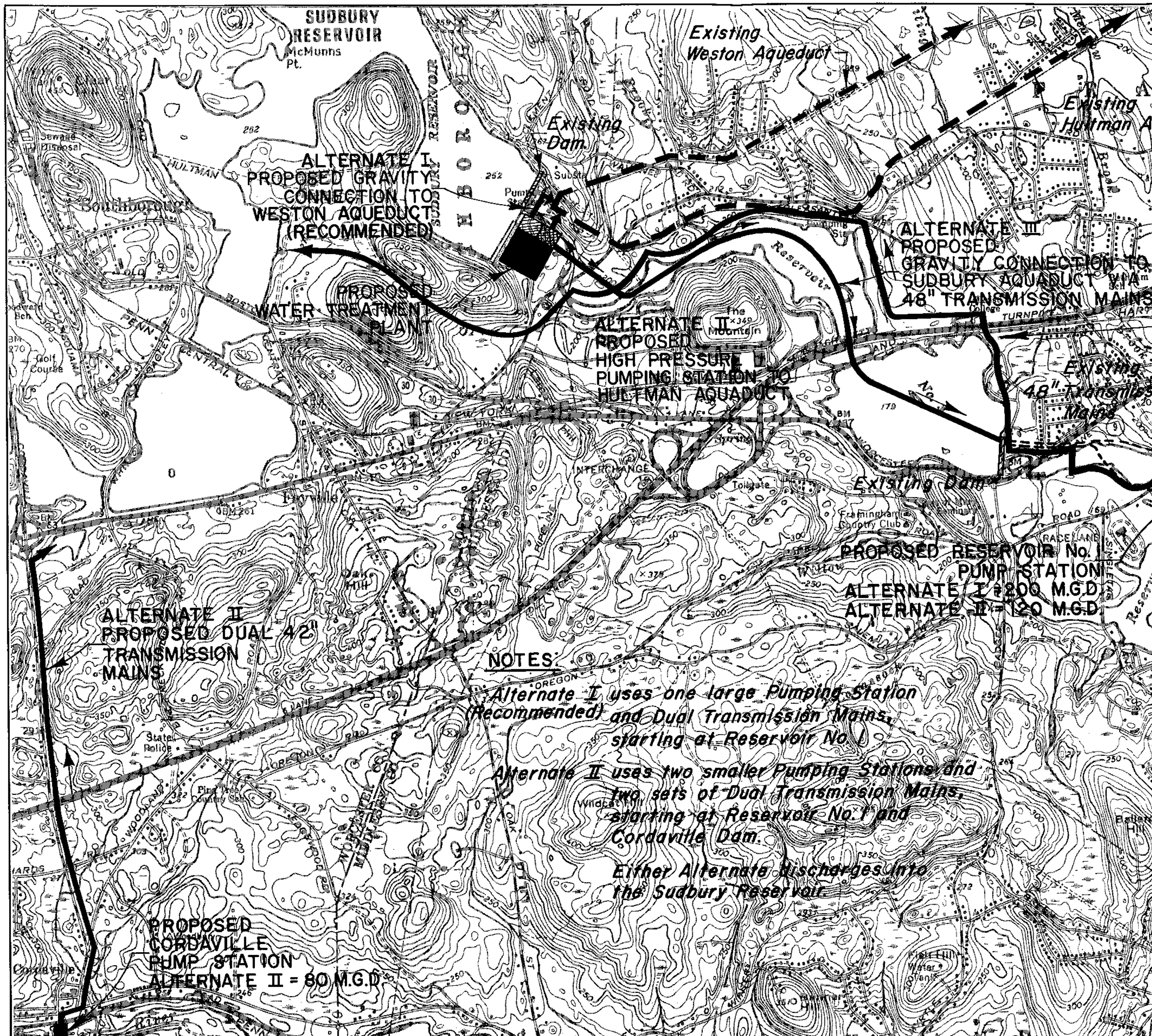
170. The Sudbury River reservoir system, as discussed earlier, was the first major undertaking by the Metropolitan Water District, a forerunner of the Metropolitan District Commission. Although used extensively since the turn of the century, the system's lower quality water and the availability of supply from Quabbin Reservoir caused the system to be placed largely in a reserve status in 1947. In recognition of the need for future water within the region, the possible redevelopment of this source for full time use has recently been investigated.

171. On the basis of the recent study, possible redevelopment of this watershed could yield from 1.5 to 51 mgd depending on the sizing of necessary facilities and operational schedule. Since the study is still underway, a selection of the "best" alternative has not yet been made. However, for purposes of this study, it has been assumed that Allocation Plan B, as designated by the MDC's consultant, will be the most favorable alternative. This is shown on Plate 26.

172. In Allocation Plan B, a 100 mgd water treatment plant consisting of a microstraining and ozonation plant would be constructed downstream from the existing Sudbury Reservoir. Water from the reservoir's natural 27.7 square mile drainage area would be withdrawn during high flow periods, treated and delivered to the Weston aqueduct. Water from the remaining 47.5 square miles of the Sudbury system would be withdrawn from the vicinity of Dam No. 1 and pumped through two 60" diameter 4.2 mile pipelines to Sudbury Reservoir. This water would also be available for treatment and delivery to Weston aqueduct.

173. Total costs for Allocation Plan B, as shown in Table G-9, would total about $48 million with an annual cost of about $4 million. Costs for water delivered from this plan would be about 32 cents per 1000 gallons or $320 per million gallons.

174. In the evaluation of Plan B, the MDC's consultant assessed the plan's impact on other uses of the resource, including water fowl, fisheries, wetlands, municipal and industrial water supply and wastewater disposal, recreation, flood protection, low flow augmentation and evaporation. Overall, the consultant concluded that Plan B could be implemented with a minimum impact on these allied water uses. The report, however, as discussed earlier is in draft status and new information is presently being developed. Whether this new data will change the consultant's conclusions is unknown at this time. For purposes of this report, however, the plan has been included as a viable alternative.



NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

PROPOSED LOCATION AND LAYOUT OF SUDBURY RIVER BASIN REDEVELOPMENT

PLATE 26

175. The additional yield estimated to be developed from this project is about 35 mgd. The project, therefore, by itself could not meet the region's entire long range supply need. However, development of the project, which would utilize resources already within the jurisdiction of the MDC, could expect to minimize institutional requirements. Implementation of the project, therefore, should be able to be realized more rapidly than several of the other structural alternatives which involve interregional and perhaps interstate resolution of disputes.

Sudbury Redevelopment Plan
Construction Cost Estimates
Table G-9

<u>First Cost</u>		
Water Treatment Plant (100 mgd)	$	12,834,000
Pumping Station		6,845,000
60'' Dual Transmission Mains		11,658,000
Connection to Weston Aqueduct		214,000
		31,551,000
Contingencies (20%)		6,310,000
		37,861,000
Engineering & Design (12.1%)		4,581,000
		42,442,000
Supervision and Administration (7.9%)		2,991,000
Total Project First Cost		45,433,000
Interest During Construction		2,783,000
Investment		48,216,000
<u>Annual Charges</u>		
Interest and Amortization		3,112,000
Operation and Maintenance (Jan. 75)		913,000
Total Annual Charges		4,025,000

Cost per 1,000 gallons = $ .32

CONNECTICUT RIVER BASIN

176. In considering projects to meet the estimated long range water supply needs which could be met by further development of the Connecticut River Basin, it was assumed that projects adequate to meet short term needs would have been constructed. In Section C, the Northfield Mountain and Millers River Basin projects are described as recommended short term Connecticut River Basin developments. Therefore, the project described in this section would be in addition to those developments.

177. The alternative project which would be constructed to meet the 210 mgd long range needs of the eastern Massachusetts region would utilize a high flow withdrawal technique. The development of this plan, shown on Plate 27, would require construction of an intake on the mainstem Connecticut River in the vicinity of Hadley, Massachusetts, a major high lift pumping installation and a connecting 16 foot diameter tunnel 9.8 miles to Quabbin Reservoir. From Quabbin a new 10 foot diameter tunnel [1] 24.2 miles long would connect to Wachusett Reservoir. From Wachusett, major modifications would be necessary to the existing regional aqueduct system to provide service to the primary transmission pipelines. Included in these modifications would be a 1.8 mile, 12.5 foot diameter pressure aqueduct from Shaft C to Shaft 1 and an 18 mile 10 foot diameter tunnel from Norumbega Reservoir to Shaft 9A. Pumping facilities would also be required on the 10 foot tunnel.

178. As illustrated on Table G-10, construction costs for development of this alternative total about $479 million with an annual cost of about $23 million for those facilities needed to deliver the water to Quabbin Reservoir and the remaining $23 million is for the conveyance facilities needed to transport the water to the consumer.

179. The operation of this plan for water supply purposes would be similar to those proposed for the short term projects. When flow in the mainstem Connecticut River, as measured at Montague City, are 17,000 cfs or greater, diversions to Quabbin Reservoir at a maximum rate of 1650 cfs would be accomplished. The flow diverted would be stored in Quabbin Reservoir and drawn upon as needs required.

180. Necessary treatment processes for the diverted water are assumed to be microstraining, ozonation and disinfection. This assumption is based largely on the future water quality in the Connecticut River with full implementation of the provisions of Public Law 92-500, Water Quality Act Amendment of 1972. The drinking water criteria now being prepared under the provisions of the Public Law 93-523 - the Safe Drinking Water Act, however, may be

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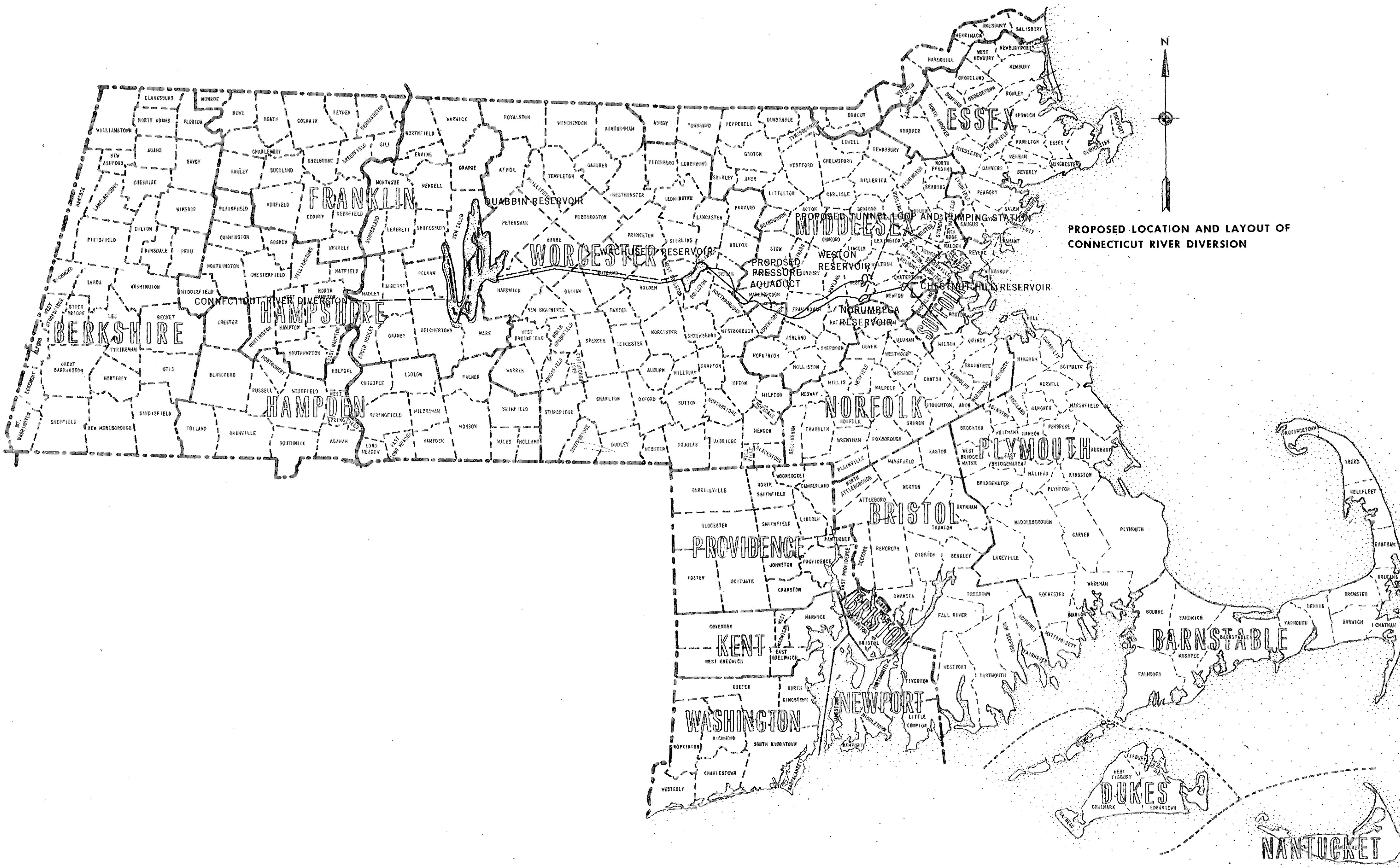
[1] The requirement for this new tunnel is a conservative approach, further studies would be needed prior to its implementation.



PROPOSED LOCATION AND LAYOUT OF CONNECTICUT RIVER DIVERSION

PLATE 27

Table G-10

Connecticut River Withdrawal
Construction Cost Estimates

<u>Project First Cost</u>

Tunnel - Connecticut River to Quabbin Reservoir - 16 foot diameter	$ 55,600,000
Pumping Station - Connecticut River to Quabbin Reservoir	101,100,000
Tunnel - Quabbin Reservoir to Wachusett Reservoir - 10 foot diameter	79,190,000
Water Treatment Plant (210 mgd capacity)	27,000,000
Pressure Aqueduct Shaft C to Shaft 1	8,919,000
Tunnel - Norumbega-Weston to Shaft 9A	59,412,000
Pumping Station	1,644,000
	$332,865,000
Contingencies	66,573,000
Engineering and Design	48,332,000
Supervision and Administration	31,556,000
Total Project First Cost	$479,326,000
Interest During Construction	58,717,000
Investment	$538,043,000

Table G-10 (Cont'd)

<u>Annual Charges</u>	
Interest and Amortization	$34,731,000
Operation and Maintenance	10,490,000
Major Replacement	639,000
Total Annual Charges	$45,860,000
Cost per 1,000 Gallons	$0.60

more stringent. If other major treatment facilities are later found necessary because of the Safe Drinking Water Act, these would add substantials to the development costs shown in Table G-10.

181. Aside from the high development costs for this alternative, there are also a number of environmental and socio-economic impacts which could be expected. Although the Quabbin storage reservoir is reported to be the largest single purpose water supply reservoir in the world, the yield sought by this plan would tax even this reservoir's capability. Draw-downs of storage would vary over a large range most of the years and as a result exposed banks and shallow areas would occur frequently. Vegetative growth could be expected in these areas and subsequent inundation and die away could cause some deterioration of the water quality.

182. Environmental impacts downstream from the intake itself and in the Connecticut River estuary are not expected to be major, primarily because of the 17,000 cfs control flow established for operation of the project. The valley residents perception of such impacts can be expected, however, to be negative toward the project.

183. Socio-economic impacts caused by the project itself are not in a quantitative sense expected to be large. The project, for example, is not expected to affect downstream water supply; industrial development; recreation use; or fish and wildlife. Based, however, on the response to the earlier mentioned Northfield Mountain and Millers River project, it can be safely assumed that any further diversion from the valley will meet strong opposition.

184. A special consideration which must be included in this plan's evaluation is the state of Connecticut's position on upstream diversion projects. This downstream state is opposed to further diversion by Massachusetts from the Connecticut River Basin. In correspondence regarding the Northfield Mountain and Millers River Basin projects, Connecticut expressed concern and the opinion that those projects set a precedent for future diversions. If this alternative were implemented, strong opposition could be expected from Connecticut.

PLYMOUTH COUNTY GROUNDWATER

185. The potential of the groundwater resources in Plymouth County was discussed earlier. As stated before, the investigations by the United States Geological Survey (USGS) indicate that the Plymouth County area has sufficient aquifers which could sustain up to a 300 mgd yield. Since this potential

exceeds the 210 mgd long range needs of the eastern Massachusetts region, development of this valuable resource was investigated as an alternative supply source.

186. The USGS study was based upon an analysis and evaluation of all available data. No new explorations were undertaken nor were test wells used to verify the quantities of water estimated. As a result, any pinpoint location of the necessary well fields would be highly speculative. The cost estimates prepared and described later, therefore, are based on a number of assumptions. These are:

1. The groundwater reservoirs supplying the wells are rectangular and can be located adjacent to one another.

2. Wells were sized to produce 1.0 mgd yields.

3. Land requirements for protection of the individual wells are those specified by the responsible Massachusetts health officials.

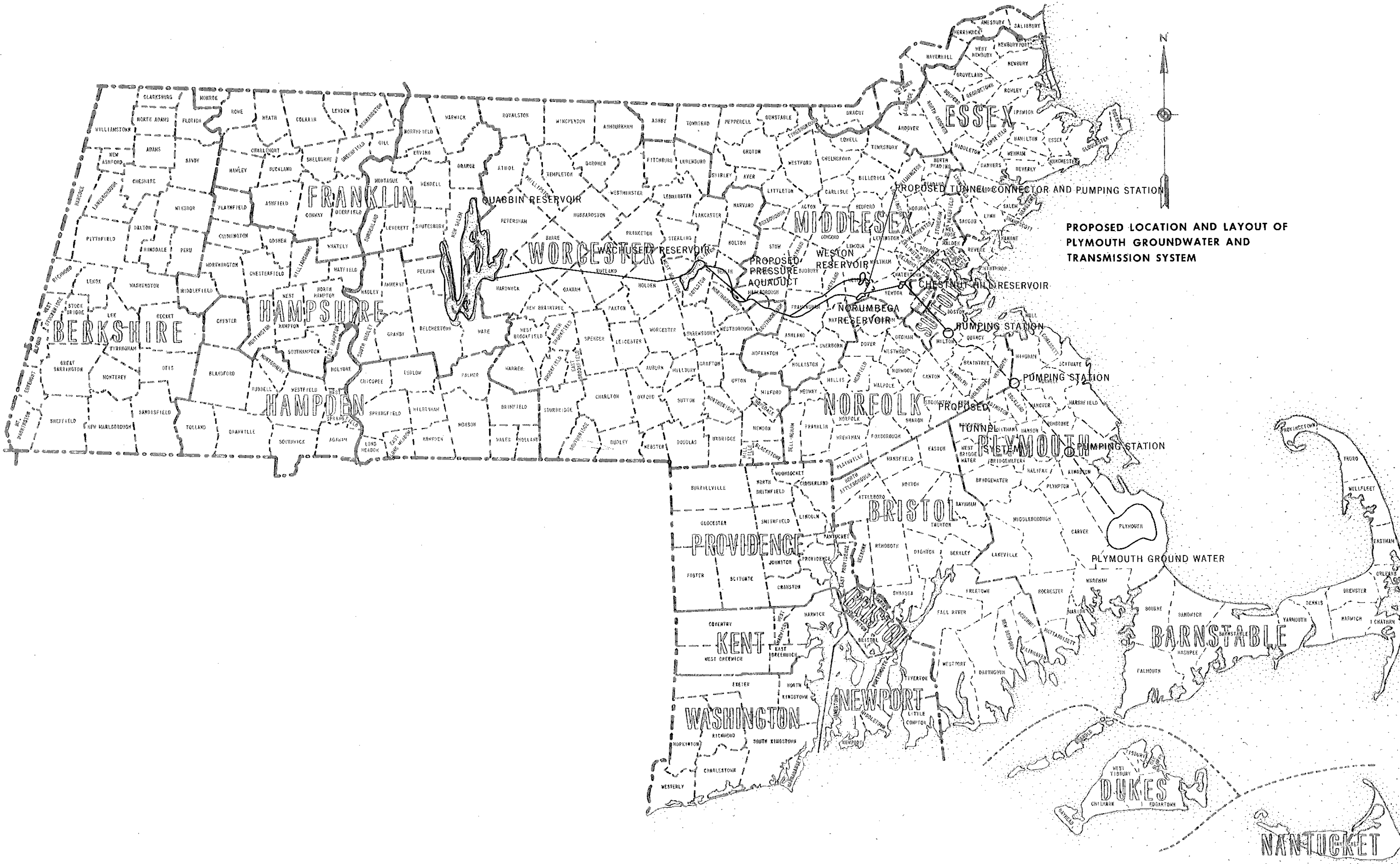
4. Based on experiences within the region, groundwater supplies can be expected to contain high concentrations of iron and manganese.

5. Pumping head at the well site is 200 feet.

6. Well fields would be used to supply base load needs and peak load periods would be served by surface water storage within the service area.

7. Connection of the well field transmission pipeline would be made to the closest feasible regional system aqueduct.

187. Major items necessary for development of the Plymouth County groundwater aquifer, shown on Plate 28, include the 210 gravel packed wells; a collection manifold system; facilities for iron and manganese removal; a 35 mile, 8 foot diameter transmission pipeline to the nearest existing regional aqueduct and high lift pumping stations to supply the necessary head for conveyance of the supply. In order to convey the supply within the service area, additions to the existing regional aqueduct system would also be necessary. These include the construction of 1.8 miles of a second aqueduct from Shaft C to Shaft 1 of the existing MDC system and a connecting 1 mile, 10 foot diameter tunnel from the Weston to the Norumbega Reservoir with a pumping station.



PROPOSED LOCATION AND LAYOUT OF PLYMOUTH GROUNDWATER AND TRANSMISSION SYSTEM

PLATE 28

188. Table G-11 illustrates the construction and annual costs associated with development of this alternative. As shown, total project cost to deliver the water to the regional aqueduct would be about $275 million. To this figure must be added about $22 million for improvements to the regional system. These improvements would add an estimated $2 million to the annual costs. Overall, these developments of the Plymouth County groundwater with improvements to the primary regional aqueduct system would have a construction cost of $342 million with an accompanying annual cost of about $37 million. Water produced from this system would cost about 48 cents per 1,000 gallons produced.

189. Aside from the high economic costs, this alternative also has high potential environmental and socio-economic effects. A major socio-economic impact which has been identified is the large quantity of land which would be required. The Massachusetts Department of Public Health requires a minimum of a 400 foot radius for protection of the well field. Recognizing that any land acquisition would follow the actually owned tracts of land rather than only the necessary health requirements, each well has been assumed to need a plot of land 1000 feet square (rather than 800' diameter). Total land requirements for development of the well field itself have been estimated to be about 4,800 acres for the 210 mgd yield.

190. The 4,800 acres or about 7.5 square miles of land necessary for the well field represents a major land taking. Such a withdrawal of land in a prime growth area can be expected to have a significant impact. In addition, the protection of recharge areas not within the purchased land boundary may require zoning changes and the restriction of potentially hazardous development activities well beyond the 7.5 square miles of the well field itself.

191. In the estimation of costs for this alternative, no cost has been assigned to tax payments lost to the affected communities. It has been the practice in Massachusetts that in land taking for water resources, the host communities are reimbursed for the taxes lost on the land. Since as described earlier, an actual pinpointing of land tracts was not possible within the scope of this study, no tax payment was estimated. However, it should be recognized such payments would probably be required if this alternative were developed.

192. Another major consideration in the development of the Plymouth County groundwater is the potential environmental impacts which could accompany such large scale withdrawals. As reported by the USGS in their work for the Southeastern New England Study (SENE) potential overdrawing of groundwater in the region could lead to major undesirable effects. In much of the

Table G-11
Plymouth Groundwater - Eastern Massachusetts Area
Additional Yield = 210 mgd

Project First Costs	
Land Acquisition for Wells and Conduits	$ 7,875,000
Wells and Manifold System (210 - 1 mgd wells)	31,500,000
Iron and Manganese Treatment Plant	64,566,000
Pumping Stations (Weston to Norumbega)	1,644,000
(Well field to MDC System)	20,708,000
Conduit 96" for 184,800' (35 miles) (Well field to MDC System)	66,405,000
Cost of Aqueduct 12'6" Shaft C-Shaft 1	8,919,000
Weston - Norumbega Tunnel	4,971,000
Sub-Total	$ 206,588,000
Contingencies	41,318,000
Engineering and Design	29,997,000
Supervision and Administration	19,585,000
Total Project First Cost	$ 297,488,000
Interest During Construction	44,904,000
Investment	$ 342,392,000
Annual Charges	
Interest and Amortization	$ 22,101,000
Operation and Maintenance	14,459,000
Major Replacement	184,000
Total Annual Charges	$ 36,744,000
Cost per 1,000 Gallons	$ 0.48

region, highly permeable aquifer material allows construction of wells which could affect pond levels, cranberry-bog water levels and streamflow. Most of the groundwater aquifers are in hydraulic connection with ponds, bogs and streams and some or even most of the groundwater withdrawn from the well field will be replaced through infiltration from these surface water bodies. With few exceptions, pond and bog levels are surface expressions of the water table. Therefore, major withdrawals from the region as would be required by this alternative can be expected to dramatically affect the region's large cranberry industry and use of the ponds as water supply and recreation facilities.

193. A second major environmental consideration in development of the Plymouth County well field relates to water quality. As stated earlier, the area's groundwater is naturally high in concentrations of iron and manganese and treatment facilities have been included in the necessary development costs. There are also a number of other water quality concerns which must be considered.

194. Whereas any major developments would draw water from the many cranberry bogs in the area, the threat of contamination from pesticides is a real concern. The effects of this threat have already been demonstrated in the nearby Taunton River Basin where a potential groundwater source was rejected because pesticides were detected during a pumping test. In this case, the effects of the pesticide contamination was known before the well was developed. In some cases however, the effect would not be noticed for months or years of pumping, well after the time the investment was committed to this alternative. Once an aquifer is contaminated, the effect may persist for years due to the naturally slow movement of groundwater.

195. Other cases of groundwater deterioration could be caused by deicing operations, disposal of liquid or solid wastes and urban runoff. It is possible but difficult to control all of these factors and their potential impact upon use of groundwater as a regional supply must be recognized.

196. Intrusion of the Plymouth County groundwater reservoirs by salt water from the ocean is also a threat. Fresh groundwater naturally flows from the land to the sea but withdrawals such as those in this alternative could reverse this flow. Although wells located near the shore would be particularly susceptible, salt water can migrate landward for miles. Once contaminated, the aquifers could be out of service for years and the heavy development cost of the facilities would continue for the idle installations.

DESALINATION

197. As described earlier, a number of technically feasible methods of desalting are currently available. Economic and environmental constraints are major obstacles which must be overcome.

198. In order to provide a basis for the comparison of desalting plants to other available methods of meeting the region's long term needs, a review was made of data given in a number of feasibility studies on desalination. One of these studies titled "Engineering and Economic Feasibility Study for a Combination Nuclear Power Desalting Plant" was prepared by Bechtel Corporation in December 1965. The study investigated the potential which a combination power-desalination plant might have in meeting southern California's future needs.

199. The plant considered by Bechtel would be located on an offshore man-made island to facilitate sea water intake and to minimize the effects of brine disposal. The plant, known as the Bolsa Island project, would produce 150 mgd of fresh water and about 1630 megawatts of power. Although this project was never constructed, the data contained in the study report provides a baseline from which construction and operating costs for such a facility can be estimated.

200. As stated earlier, the eastern Massachusetts' long range deficit needs are estimated to be 210 mgd beyond the capability of locally available resources. In evaluating the role which desalting may play in meeting this need, the cost estimates for the Bolsa Island project were updated to reflect current construction and operating costs and the plant size was expanded on a pro rata basis to account for the 210 mgd need which such a plant would meet.

201. As shown in Table G-12, construction costs for the portion of the plant allocated to desalting operations would be about $455 million. Water from this plant, when operating at full capacity (i.e., 210 mgd) would cost, at the plant location, about $1.30 per 1,000 gallons.

202. It must be noted that the $1.30 figure does not include necessary costs for connecting transmission pipelines to points of need and necessary improvements in the existing regional aqueduct system. The site location for such a plant would of course be subject to power plant locational criteria. If it is assumed that the fuel supply for the energy production would be nuclear (the most economical source) then Atomic Energy

Table G-12

Desalting Plant - Eastern Massachusetts Area
Additional Yield = 210 mgd

Project First Costs		
Desalting Plant		$455,000,000
Pumping Stations	(Weston to Norumbega)	1,644,000
	(Plant to MDC System)	25,945,000
Conduit 96" for 200,000 ft. (Plant to MDC System)		72,170,000
Aqueduct 12'6" Shaft C - Shaft 1		8,919,000
Weston to Norumbega 10' diameter tunnel		4,971,000
Sub-Total		$568,649,000
Contingencies		113,730,000
Engineering and Design		82,568,000
Supervision and Administration		53,910,000
Total Project First Cost		818,857,000
Interest During Construction		124,738,000
Investment		$943,595,000
Annual Charges		
Interest and Amortization		$ 60,909,000
Operation and Maintenance		66,635,000
Major Replacement		8,189,000
Total Annual Charges		$143,235,000
Cost per 1,000 Gallons		$1.87

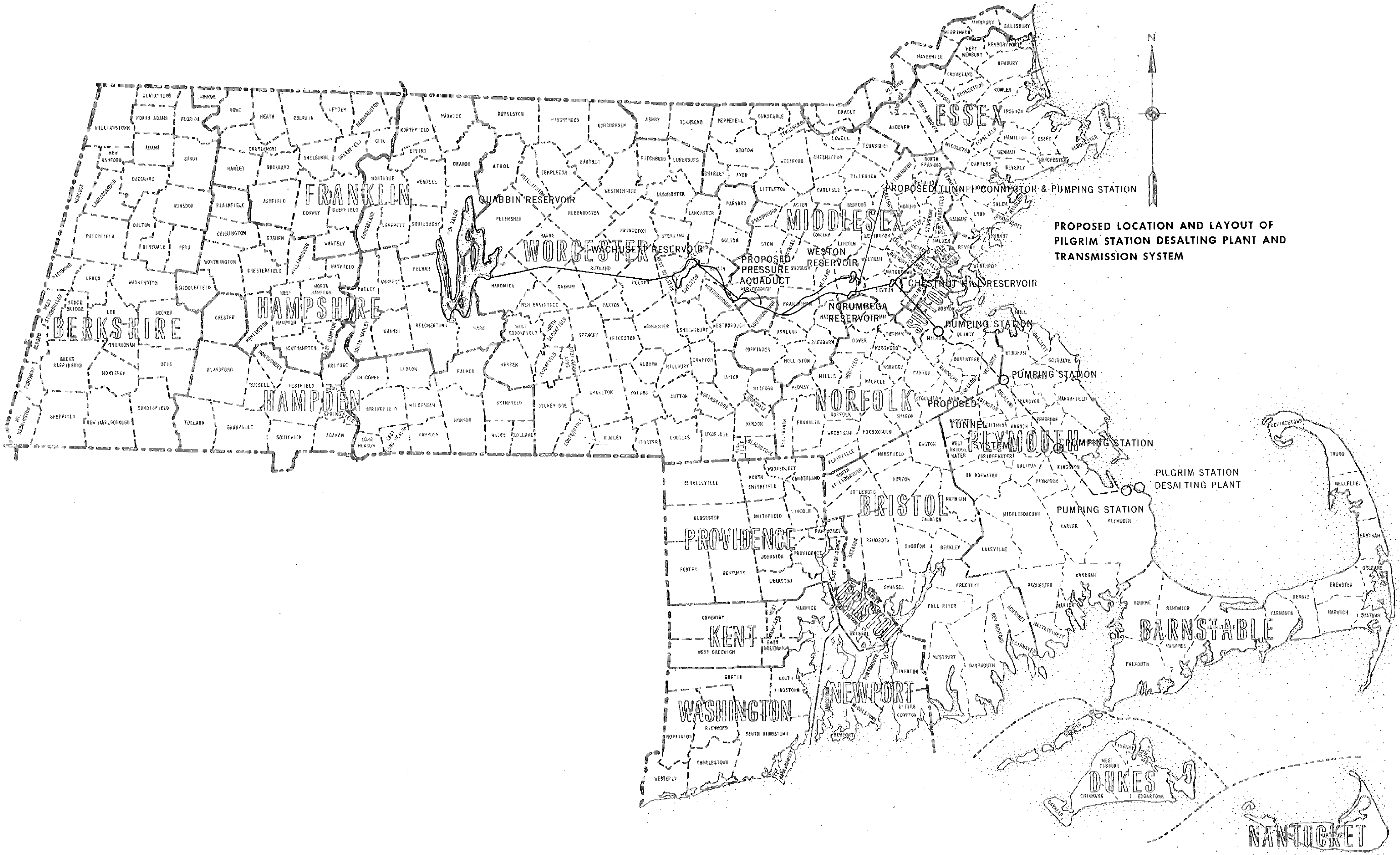
Commission regulations which require a location away from the Boston metropolitan area would be observed. In addition, any plant siting would also have to meet the criteria of the operating electric utility with regard to economic and environmental considerations.

203. Without the benefit of a major siting survey a pinpointing of an exact desalting plant is virtually impossible. However, a recently constructed nuclear power station in Plymouth, Massachusetts offers a model for a power plant which has successfully met similar type criteria. Therefore, for purposes of this study, a location in proximity to the existing Plymouth nuclear station, shown on Plate 29, was selected to demonstrate possible transmission costs from the desalting plant to the water supply demand center.

204. In order to minimize the costs for the necessary pipelines and pumping stations from the desalting plant, the facilities were sized to provide a base load supply source. Peak loads such as maximum season, month, week and day demands are considered as available from existing surface water reservoirs within the service area. Construction cost estimates for the approximately 38 miles of aqueduct would total about $104 million while pumping installations would add about $40 million to this total. Annual costs including debt service and operation and maintenance for the transmission facilities would total about $23 million, which would add about $0.30 per 1,000 gallons to the cost of water from the desalting plant. Altogether then the cost of water from such a plant could total about $944 million in capacity outlay and water would cost about $1.87 per 1,000 gallons.

205. As described earlier, the environmental costs associated with desalting operations can also be a serious consideration. Numbers of recent newspaper articles have described the possible impacts which a power plant siting may have on the environmental and socio-economic structure of the host region. Possible impacts from thermal discharges and salinity changes are considered by many as major potential environmental problem areas. All of these considerations for power plant siting are amplified by the addition of a desalting operation.

206. Waste heat from power production according to the National Water Commission report is a serious problem. The problem arises when cooling water used to cool condensers in the power generating facility is heated and discharged to the surrounding environment. Depending on the heat rise and mixing characteristics of the receiving water body, the impact may be detrimental or advantageous to the receiving water body. Many feel, however, it is apt to be detrimental.



PROPOSED LOCATION AND LAYOUT OF PILGRIM STATION DESALTING PLANT AND TRANSMISSION SYSTEM

PLATE 29

207. Desalting plants add to the waste heat in two ways: (1) by the waste heat discharged at power plants to supply energy for desalting plants and (2) by the waste heat from the desalting operation itself. This additional waste heat load for the plant necessary to meet the eastern Massachusetts long range supply needs would be significant. Based on an extrapolation from data for a 10 mgd plant the 210 mgd long range plant could discharge daily about 1,400 megawatts of waste heat to the environment.

208. As stated earlier, brine disposal from desalting operations can be a serious problem. In the assumed long range desalting plant, described earlier, the sea itself would represent the most economical and probably least damaging method of disposal. However, the large quantity of brine, about 105 mgd with 42,000 tons of salt daily, could have dramatic effects on the local ecology. In order to minimize this impact, the use of diffusers to insure adequate dilution may be necessary. The costs for these facilities would of course have to be added to the cost of the desalting plant construction cost shown in Table G-12.

209. In addition to the environmental impacts described above, the desalting plant similar to a power plant can also affect the socio-economic composition of the region. These effects can be positive or negative and range from quantifiable effects on employment, income and taxes to less tangible impacts such as those on transportation, housing, recreation and demand for public services. These impacts, however, are not unique to desalting plants. Any large capital investment could produce similar impacts. Without the benefit of a detailed investigation for each of the long range alternatives which is beyond the scope of this study, a quantification of each of these effects is not possible. However, several significant impacts for all alternatives have been identified and these are shown in the next section, "Comparison of Alternatives".

COMPARISON OF ALTERNATIVES

210. In comparing the long term alternatives, a number of possible project effects are, to a large degree, common to all. For example, the provision of an adequate water supply, regardless of its source, can be expected to have similar environmental and socio-economic impacts within the service area. Table G-13, therefore, does not describe all of the impacts associated with the project, but rather those considerations identified to date which vary among the projects. Because the long term alternatives did not enjoy the same detail of investigation as the short term plans, the considerations shown may not be all inclusive. Further studies may reveal other areas which would influence the selection of a long term plan. The considerations described, however, do reflect input gathered during public participation on the alternatives.

211. From an economic viewpoint, the least costly alternatives would be the Sudbury River redevelopment and Demand Modification. Each of these projects, by themselves or in combination, however, could not meet the region's long term supply needs. Of those alternatives which could provide the total future long term needs, development of the Merrimack River mainstem or Plymouth County groundwater offer the least costly supply.

212. In terms of Reliability and Flexibility, both Plymouth County groundwater and Desalination rank lowest in attaining these objectives. Both Sudbury River redevelopment and Demand Modification are unable to meet the total long term need and Demand Modification results are unproven to date; therefore, their reliability to meet future needs by themselves is low. Development of the Merrimack by either high flow or continuous withdrawals appear to offer the best opportunity to meet both objectives.

213. With regard to timeliness, all of the alternatives except Merrimack River-Continuous Withdrawal and the Connecticut River projects could be fully implemented in time to meet the long term needs. The major question on the Merrimack-Continuous Withdrawal plan is the implementation of the upstream reservoirs. If Massachusetts and New Hampshire agreed on possible joint use of the reservoirs, however, there is no physical constraint to this alternative proceeding in time to meet long term needs. A somewhat similar situation is a constraint on the Connecticut River development, i.e., the uncertainty is not caused by physical conditions but rather by socio-political concerns. Demand Modification measures can be implemented in time, however, there is some uncertainty as to its full effectiveness within the time frame considered.

TABLE G-13 LONG TERM ALTERNATIVES' COMPARISON

Considerations	Plymouth County Groundwater	Desalination	Merrimack River Mainstem-High Flow Withdrawal	Merrimack River Mainstem-Continuous Withdrawal	Sudbury River Redevelopment[1]	Connecticut River	Demand Modification[1]
A. Economic and Engineering							
Yield (mgd)	210	210	210	210	35	210	30
Investment	$342.4 million	$943.6 million	$495.3 million	$440.2 million	$48.2 million	$538.0 million	
Annual Charges	$ 36.7 million	$143.2 million	$ 41.3 million	$ 36.7 million	$ 4.0 million	$ 45.9 million	
Cost per 1,000 Gallons	$0.48	$1.87	$0.54	$0.48	$0.32	$0.60	
Reliability	Full yield may not be attainable; water quality may deteriorate with use due to contamination from pesticides, urban runoff and salt water intrusion.	Development of a prototype to yield quantity desired not yet achieved; operation depends on power plant output which has been interuptible in nuclear fueled plants.	Historic natural flow has been available to support yield; water treatment plant should insure high quality supply; upstream major future withdrawals could affect operation.	Operation depends to large extent on upstream reservoir storage; water treatment plant should insure high quality water.	Historic natural flow has been available to support yield; water treatment plant should insure high quality water.	Historic natural flow has been available to support yield; diversion to Quabbin Reservoir may affect water quality; water treatment plant should insure high quality water to consumers.	Consumer education and water saving appliances have not been applied in a large scale application; full "savings" may not be realized.
Flexibility	Well field construction can be staged; transmission pipeline, however, must be completed at outset; if difficulties arise with water quality, well fields may require long time periods before available for use.	Plant may be constructed in modules; transmission pipeline, however, must be completed at outset; if energy or maintenance costs are higher than expected in the prototype transmission aqueduct could be major economic loss.	Plant may be constructed in stages but connecting aqueducts would be required at outset; plant treatment processes have ability to treat varying water quality.	Initial construction could proceed without upstream reservoirs; plant could be constructed in stages but connecting aqueducts would be required at outset; plant treatment processes have ability to treat varying water quality.	Plant locations as proposed could feed only lower pressure service areas; pumping station would be needed to service other pressure zones;	Pumping station could be staged; tunnel to Quabbin Reservoir would be required at outset; treatment plant, aqueduct to Wachusett Reservoir and improvements to primary regional aqueduct system could be constructed as needed.	Results of demand modification could be monitored and either new methods employed or another alternative implemented.
Timeliness	Could be developed to meet long term needs.	Could be developed to meet long term needs.	Could be developed to meet long term needs.	Upstream reservoirs may not be implemented in time to realize full yield because of opposition.	Could be developed to meet long term needs.	May not be implemented in time to meet long term needs because of downstream state opposition.	Because such a wide scale application has not been implemented before, the realization of full benefits of this method is uncertain.
Equity	Alternative would transfer water resources to out of basin users; resource would be used in same state in which the resource is located.	Plant location would be separate from users; impacts of plant, if any, would be diverted from consumers of water produced.	Alternative would transfer water resource to primarily out of basin users; resource would be used in same state in which the resource is located.	Alternative would transfer water resource to primarily out of basin users; resource would be used in same state in which the resource is used; upstream reservoir development, however, would be located in New Hampshire, which would not benefit directly from the project's supply.	Alternative would transfer water resources to some out of basin users; resource would be used in same state in which the resource is located.	Alternative would transfer water resources for primarily out of basin users; resource would be used in same state in which the project is located; river is interstate, however, and downstream interest would not receive full river flow.	Beneficiaries would implement water saving techniques; costs would be directly borne by beneficiaries.

[1] A Study of the Upper Sudbury River Watershed for the Metropolitan District Commission Commonwealth of Massachusetts by C.E. Maguire, Inc., 1975

[2] Water Demand Study, Eastern Massachusetts Region, prepared for New England Division, Corps of Engineers by Coffin and Richardson, Inc., November 1974.

TABLE G-13 LONG TERM ALTERNATIVES' COMPARISON (CONT.)

Considerations	Plymouth County Groundwater	Desalination	Merrimack River Mainstem-High Flow Withdrawal	Merrimack River Mainstem-Continuous Withdrawal	Sudbury River Redevelopment	Connecticut River	Demand Modification
B. Environmental							
Upstream from Project Area	More stringent methods to protect well fields can be expected.	N/A	Close attention to water quality implementation plans can be expected; once implemented followup inspections to insure efficient operation of plants and control of non-point sources would be needed.	Close attention to water quality implementation plans can be expected; once implemented followup inspections to insure efficient operation of plans and control of non-point sources would be needed. Upstream reservoirs will inundate present free flowing streams; stream fisheries will be affected; current land use in reservoir areas will be changed.	More stringent methods to protect upstream watershed can be expected.	Close attention to water quality implementation plans can be expected; once implemented followup inspections to insure effecient operation of plants and control of non-point sources would be needed.	N/A
Immediate Project Area (Eastern Massachusetts)	Well field development may cause major drawdowns of existing ponds, lakes and cranberry bogs; some small streams may cease flowing during low flow periods; salt water intrusion may affect well development within and adjacent to project area; water quality may be impaired.	Impacts from thermal discharges and salinity changes could be detrimental to local ecology and environment; cooling towers may affect local climatic conditions;	Since operational control flows are based on minimizing environmental damage impacts should be minor in the aquatic environmental; tunnel construction will cause local noise and air pollution; rock disposal will affect the environment of spoil areas during construction.	Since operational control flows are based on minimizing environmental damage impacts should be minor in the aquatic environmental; tunnel construction will cause local noise and air pollution; rock disposal will affect the environment of spoil areas during construction.	Sudbury Reservoir regulation will cause 9-10 foot fluctuations in water elevation; shoreline areas will be exposed frequently.	Quabbin Reservoir storage will be made up primarily with Connecticut River water; storage fluctuation will expose reservoir shoreline.	Wastewater flow volumes will be reduced.
Downstream from Project Area	Small streams may cease flowing during low flow periods; water quality may be impaired; salt water intrusion may occur; downstream fisheries and related wildlife would be significantly affected.	N/A	Operational control flows were established to minimize downstream environmental impacts.	Operational control flows were established to minimize downstream environmental impacts.	Impacts are reported as minimal. Possible effects could include national wildlife preserve and nesting areas.	Operational control flows were established to minimize downstream environmental impacts.	N/A
Energy Requirements	4,360 Kw Hr/day/mg	103,330 Kw Hr/day/mg Highest energy consumer of all alternatives	2,700 Kw Hr/day/mg	2,250 Kw Hr/day/mg	535 Kw Hr/day/mg	3,700 Kw Hr/day/mg	Energy would be needed to produce water saving appliances but it has been assumed this energy need would be similar for both water saving and conventional models.

TABLE G-13 LONG TERM ALTERNATIVES' COMPARISON (CONT.)

Considerations	Plymouth County Groundwater	Desalination	Merrimack River Mainstem-High Flow Withdrawal	Merrimack River Mainstem-Continuous Withdrawal	Sudbury River Redevelopment	Connecticut River	Demand Modification
C. Socio-Economic							
Agriculture	One of Massachusetts' leading agricultural crops is cranberries; this alternative, if developed to full capacity, would impact heavily because of its drawdown of water from cranberry bogs.	N/A	About 85 acres of a working farm would be removed from that activity by the water treatment plant.	About 85 acres of a working farm would be removed from that activity by the water treatment plant. Upstream reservoirs would require the acquisition of about 1230 acres suitable for agriculture. Many of these farms, however, are no longer active in agricultural production.	None	None	None
Land Requirements	5,060 acres	360 acres	140 acres	7,680 acres	None	50 acres	None
Recreation	Many of the ponds in the area are used for recreation; drawdowns caused by the ground-water withdrawals could dramatically reduce this valuable economic resource.	Recreation opportunities in the vicinity of the plant location could be curtailed.	Since operational control flows are based on minimizing environmental damage impacts should be minimal in the vicinity of and downstream from the treatment plant.	Since operational control flows are based on minimizing environmental damage impacts should be minimal in the vicinity of and downstream from the treatment plant. Upstream reservoirs will curtail as well as increase recreational opportunities; recreation activities associated with free flowing streams will be reduced; lake oriented recreation will increase.	None reported by MDC consultant.	Operational control flows should minimize any impacts.	None
Employment	Employment opportunities for construction and operation of the facilities should be significant; if Massachusetts' current unemployment rate should continue into the future then project employment opportunities should be welcomed.	Employment opportunities for construction and operation of the facilities should be significant; if Massachusetts' current unemployment rate should continue into the future then project employment opportunities should be welcomed.	Employment opportunities for construction and operation of the facilities should be significant; if Massachusetts' current unemployment rate should continue into the future then project employment opportunities should be welcomed. The tunnel aqueduct construction would require some specialities not generally found in the local labor market, therefore, impacts on employment will be lowered somewhat.	Employment opportunities for construction and operation of the facilities should be significant; if Massachusetts' current unemployment rate should continue into the future then project employment opportunities should be welcomed. The tunnel aqueduct construction would require some specialities not generally found in the local labor market, therefore, impacts on employment will be lowered somewhat. Upstream reservoir construction should stimulate employment opportunities within New Hampshire.	Local employment opportunities should increase but not significantly.	Employment opportunities for construction and operation of the facilities should be significant; if Massachusetts' current unemployment rate should continue into the future then project employment opportunities should be welcomed. The tunnel aqueduct construction would require some specialities not generally found in the local labor market, therefore, impacts on employment will be lowered somewhat.	Majority of water saving appliances are manufactured out of state; no local employment opportunities should be gained.

TABLE G-13 LONG TERM ALTERNATIVES' COMPARISON (CONT.)

Considerations	Plymouth County Groundwater	Desalination	Merrimack River Mainstem-High Flow Withdrawal	Merrimack River Mainstem-Continuous Withdrawal	Sudbury River Redevelopment	Connecticut River	Demand Modification
C. Socio-Economic (Cont'd)							
Municipal Finances	Large land requirements could affect tax base of communities in which well fields are located; annual costs over serviced population would equal $8.43 per capita.	Annual costs over serviced population would equal $32.55 per capita.	Annual costs over serviced population would equal $8.80 per capita.	Annual costs over serviced population would total $7.89 per capita.	Alternative does not provide total long term need.	Annual costs over serviced population would total $9.80 per capita.	No Effect
Displacement of People	High	Low	Low	High	None	Low	None
Institutional Relationships	Development would be in-state; new institution probably would be required since no existing state agency has legislative authority over the broad service area.	Development would be in-state; because of the requirement for the power plant a new unique state institution would be needed.	Development would be in-state but river is interstate; arrangements between New Hampshire and Massachusetts may be necessary.	Upstream storage reservoirs are in New Hampshire; extensive arrangements between New Hampshire and Massachusetts would be needed.	Development would be in-state and affect facilities currently operated by MDC; no new institutional arrangements may be necessary.	Development would be in-state but river is interstate; arrangements between Massachusetts and Connecticut may be necessary.	Changes in State and local plumbing codes may be necessary.

[1] Alternative does not meet total long term need.

214. All of the alternatives except Demand Modification would transfer a resource to a point of need in some cases not within the basin of origin. Two of the sources; namely, the Merrimack and Connecticut, are interstate rivers and the questions of equitable distribution are further complicated in these cases by political boundaries.

215. Environmental impacts can be expected to be largest with the Merrimack River-Continuous Withdrawal plan because of the upstream reservoirs involved. All other alternatives do not require upstream facilities constructed directly as part of the project and therefore limited impacts are expected.

216. All of the alternatives which require new construction can be expected to have an environmental impact within the project area itself. Of these, the impacts associated with the Plymouth County groundwater, Desalination and the Connecticut River alternatives should be the largest, however.

217. Downstream from the project area the groundwater alternative again appears to pose the greatest environmental impact potential. Other alternatives which would use natural river systems as sources have utilized control flows which, through operational procedures, should minimize downstream impacts.

218. From an energy use perspective there is little doubt that Desalination would require the largest quantities of electricity. Other high energy users include the Plymouth County groundwater and Connecticut River alternatives. Although energy needs for the Merrimack and Sudbury River alternatives are certainly not low, they are lower than the other structural alternatives. Lowest of all, of course, is the Demand Modification measures.

219. In the socio-economic considerations, possible impacts upon agriculture was identified as a concern. Potential drawdowns of cranberry bogs is a major impact which could occur with implementation of the groundwater alternative. Since cranberries are a major product of the Massachusetts agricultural market, any interruption of this activity as might occur with the groundwater alternative could have significant impacts. The Merrimack developments would also affect agricultural activities, but the continuous withdrawal plan would have the more significant effects.

220. Land requirements vary from no additional land needed for the Demand Modification alternative to a high of about 7,600 acres with the Merrimack Continuous Withdrawal plan. Since the majority of land

taking for the Merrimack plan would be in New Hampshire, the possible socio-economic impacts are multiplied by the upstream versus downstream conflicts which accompany such developments. The Plymouth County groundwater alternative would also require large tracts of land. The impact of this land withdrawal from a fast growing area of Massachusetts, therefore, could be expected to have significant impacts.

221. Recreation, both existing and potential, should be affected most heavily by the Plymouth County groundwater alternative. Excessive draw-downs of natural lakes within the region would limit severely both water contact and water related activities. The upstream reservoirs associated with the Merrimack Continuous Withdrawal plan should offer a mix of impacts on recreation; with stream oriented activities replaced by lake related opportunities. Whether lake based recreation will exceed or be less than the stream opportunities lost is unknown at this time.

222. Employment opportunities brought about by any of the alternatives except Demand Modification would increase with implementation of any of the alternatives. These opportunities would include increased employment during construction and later during the operation of the projects. In those alternatives which require tunnel construction, some hires probably would be required having specialities generally found outside of the region. Therefore, for these facilities, the impact on local employment will be moderated somewhat by the necessary importation of certain skills. Overall, however, implementation of the projects would provide significant employment opportunities in an area where, at present, unemployment figures in all construction trades are quite high. Operation and maintenance activities would offer employment opportunities that are longer lasting than those associated with construction. Treatment and pumping station operation would require a mix of skilled and unskilled labor and therefore a wide range of the labor market could be expected to be impacted upon. In addition to the employment opportunities directly associated with the construction, operation and maintenance of the projects, the alternatives would also impact upon service sector employment. Salaries spent locally as well as local procurement of supplies in turn will increase the demand for service sector personnel. Increased business activity and employment in the local service sector can be expected to have a multiplier effect on the local economy, therefore, creating additional local regional income.

223. Municipal finances could be affected by all of the alternatives except Demand Modification. Two major effects could occur. The first would be through the serviced communities repaying the capital and operating costs of the projects. The second impact could be caused by the land taking associated with the various alternatives. Of all the structural alternatives, Desalination would cause the highest repayment requirements (about four

times that of other alternatives). Development of any of the other structural measures would cost each serviced consumer about $8 to $9 more per annum. Land requirements for the alternatives could affect local tax bases and development plants of the host communities. For this impact, the Merrimack River Mainstem-Continuous Withdrawal and Plymouth County groundwater alternatives require the highest land takings. Even though specific site investigations were not conducted, these alternatives, therefore, could be expected to have the largest impacts on municipal finances. If as in the past, however, compensation were offered for lost tax revenue, this impact could be reduced markedly.

224. In the planning of all alternatives, facilities were located and routed such that displacement of people would be held to a minimum. In the development of any large scale facilities in urban areas, however, some displacement would be required. By virtue of their large land requirements, both the Merrimack River Mainstem-Continuous Withdrawal and Plymouth County groundwater alternatives are considered to have the highest impact. The lack of detailed specific site investigations precluded a quantification of this impact but observation of the general project area indicates the relative rating of these alternatives is valid.

225. All of the long term alternatives would affect existing institutional arrangements. Some such as Plymouth County groundwater, Desalination, Sudbury River redevelopment and Demand Modification affect only Massachusetts and therefore only that state's modification of existing institutions may be required. Others such as the Merrimack River mainstem high flow withdrawal and Connecticut River require in-state project construction but draw from an interstate river. Therefore, these two alternatives could require some interstate cooperation. The last alternative, Merrimack River Mainstem-Continuous Withdrawal, has project components in two states; New Hampshire and Massachusetts, and necessary institutional changes could affect both states.

NECESSARY FUTURE ACTIONS

226. From the data described earlier, two of the long term projects; namely, Sudbury River redevelopment and Demand Modification, appear to be favorable components as part of a long term regional plan. Each of these projects would yield a cost effective, limited impact increment to the estimated long term need. The two projects, however, even in combination would not meet the long term need forecast for the region. Implementation of one of the other alternatives would be necessary, therefore, to provide an adequate supply for the region through 2020.

227. A review of the other alternatives with their economic costs and associated environmental and socio-economic impacts indicates the two most favorable alternatives to supplement those described above would be the Plymouth County groundwater and Merrimack River mainstem projects. The other available alternatives, namely, Desalination and Connecticut River appear too costly and have high environmental and socio-economic impacts which detract from their desirability.

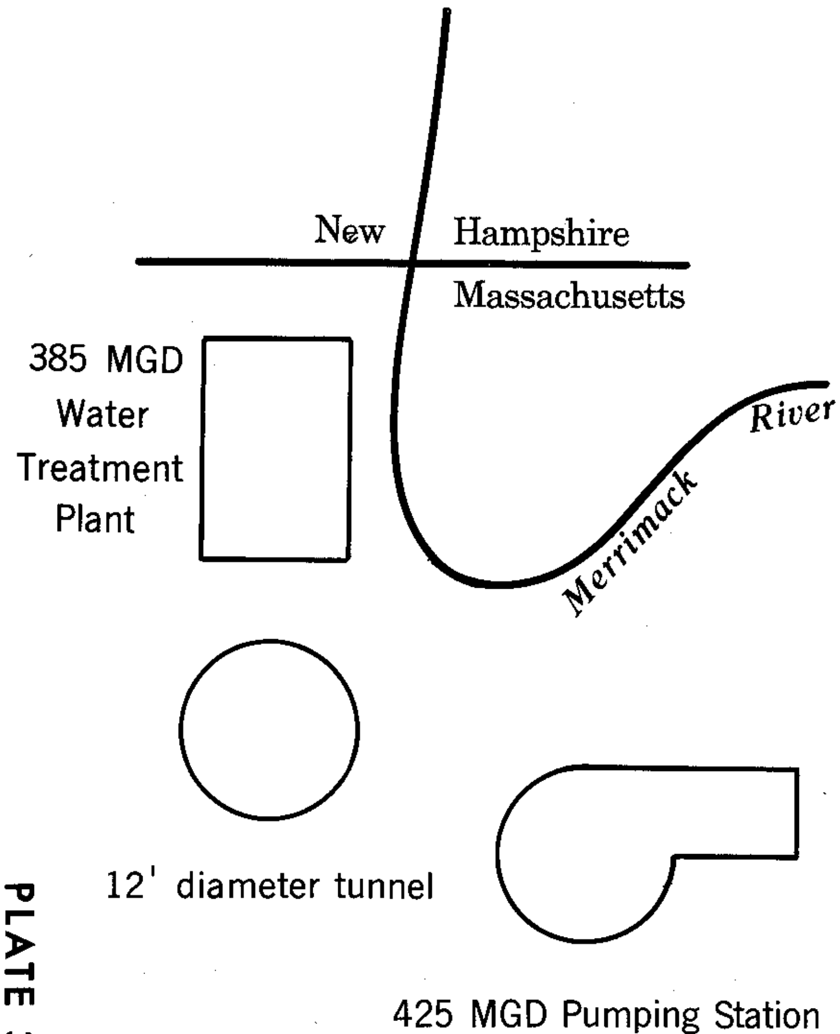
228. Both the Plymouth groundwater and Merrimack mainstem developments, however, also have a number of uncertainties which should be resolved before a firm choice can be made. The major question on the Plymouth development is the significant environmental and socio-economic impacts which could occur with its development. The scope of this study did not allow a quantification of these impacts, but based on available data and information from the U.S. Biological Survey, large scale withdrawals from this area would have dramatic effects. A delineation of these impacts is a prerequisite in the further evaluation of this alternative.

229. Development of the Merrimack River mainstem also has a number of uncertainties associated with it which should be considered further prior to final evaluation. As described earlier, the control flows used in this study were based on estimated flow needs of the anadromous fish restoration program and the existing hydroelectric facilities capacity for use of the river. The project components and construction costs based on these control flows are much higher than those which would be necessary if a lower control value based on water quality were used. A comparison of these differences is shown in Table G-14, and schematically on Plate 30. Since project costs, as illustrated in the Table, are so sensitive to the selected control flow, it is apparent that necessary further studies should focus on this issue to determine all trade offs associated with the adoption of any control flow rate.

230. A second area which should receive attention in further studies on the Merrimack is the question of upstream reservoirs. As illustrated on Tables G-13 and G-14, the least costly alternative method of developing the Merrimack, depending on the selected control flow, could be the continuous withdrawal technique. Historically, however, construction of upstream reservoirs in New Hampshire have been opposed and there is little reason to believe the necessary reservoirs for the continuous withdrawal alternative would be welcome additions. On the basis of this studies' investigations however, some of the upstream reservoir sites appear to have potential for development as multiple purpose reservoirs. With such multiple purpose development, benefits could be realized by New Hampshire as well as Massachusetts. If substantial benefits were realized by New Hampshire, the state may be willing to allow construction of one or more of the reservoirs.

Comparison of Withdrawal Techniques

High Flow Skimming



Continuous Withdrawal

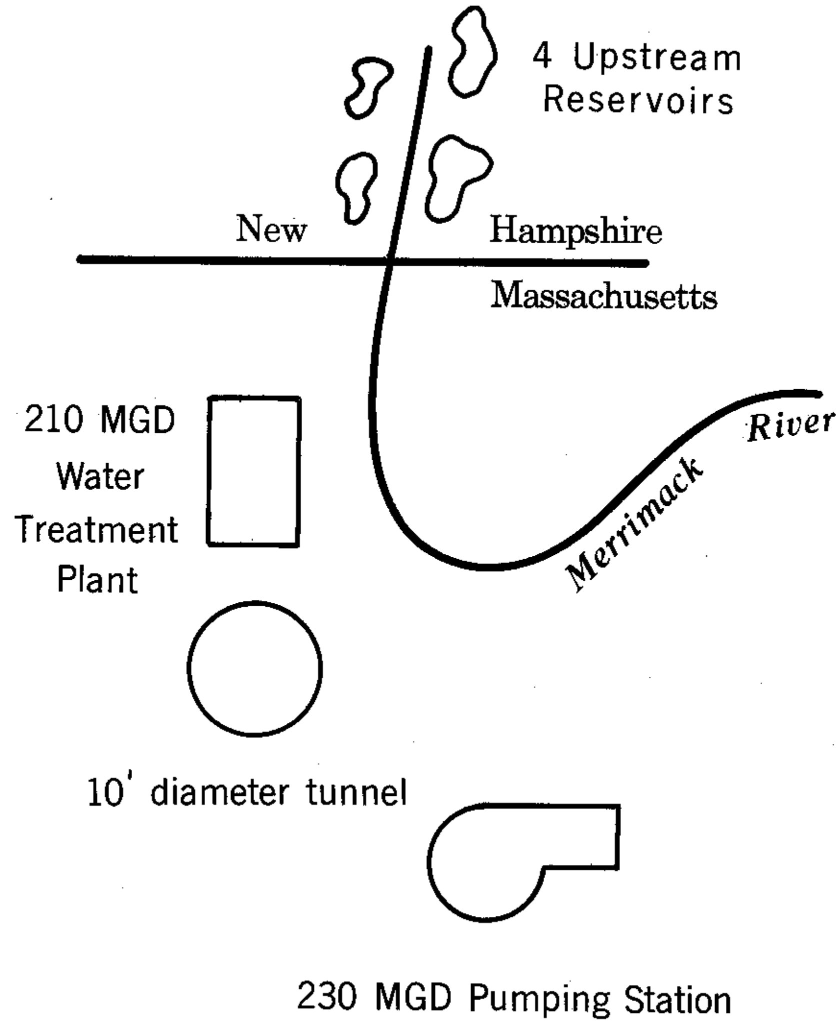


PLATE 30

TABLE G-14
Long Term Merrimack River Development Construction Costs
July 1975 Dollars [1]

Component	High Flow Skimming		Continuous Withdrawal	
	High Control Flows	Low Control Flows	High Control Flows	Low Control Flows
Treatment Plant	385 MGD @ $125.0	225 MGD @ $77.0	210 MGD @ $72.0	210 MGD @ $72.0
Reservoirs			91.5 [2]	28.3 [2]
Tunnels	12' Diameter	10' Diameter	10' Diameter	10' Diameter
All Shafts	6.3	5.7	5.7	5.7
Segment 1	$20.1	$17.0	$17.0	$17.0
Segment 2	10.7	9.8	9.8	9.8
Segment 3	11.3	9.4	9.4	9.4
Segment 4	13.8	11.3	11.3	11.3
Segment 5	17.9	14.7	14.7	14.7
Segment 6	15.3	12.7	12.7	12.7
Segment 7	14.8	12.6	12.6	12.6
Segment 8	10.1	8.2	8.2	8.2
Segment 9	9.4	7.9	7.9	7.9
Pumping Stations	$25.0	$13.4	$11.7	$11.7
MDC Improvement	8.9	8.9	8.9	8.9
Real Estate	2.0	2.0	2.0	2.0
Sub-Total	290.6	210.6	203.9	203.9
Contingencies (20%)	58.1	42.1	40.8	40.8
E & D (12.1%)	42.2	30.6	29.6	29.6
S & A (7.9%)	27.6	20.0	19.3	19.3
Sub-Total	418.6	303.3	385.1	321.9
Interest During Construction	76.7	49.7	56.7	50.9
TOTALS	495.3	353.0	441.8	372.8

[1] All Costs in Millions, ENRCCI = 2247
[2] Reservoir Costs Include Real Estate, Contingencies, Engineering and Design and Supervision and Administration
[3] Reservoir Costs not Included

231. Another area which should be investigated concerns the relationship of New Hampshire's and Massachusetts' future use of the river. Based on current information, plans by New Hampshire for future utilization of the Merrimack do not appear to impede development by Massachusetts. New Hampshire's plans, however, are preliminary and future considerations may modify their current thinking. Any further studies, therefore, which are considering the implementation of the Merrimack alternative, should consider closely the institutional arrangements which may be required to insure that the interests of both New Hampshire and Massachusetts are served.

SECTION H
SUMMARY

1. This general report has investigated and assessed all aspects of the water supply situation within the study area. Specifically, the report evaluates the water supply needs of communities within the Massachusetts portion of the Merrimack River and the potential which the river may have as a long range supply source for eastern Massachusetts. The possibility of serving the short term needs for portions of southeastern New Hampshire from the river within Massachusetts was considered and is reported upon.

2. In the development of the various alternatives, input was gathered from Federal, State, Regional Planning and Local agencies. Progress meetings were held at approximately bi-monthly intervals and interested agencies and citizens were invited to offer their opinions on the direction of the study. In addition, public meetings were held to describe the study and to solicit public input.

3. The Merrimack River Basin is located in south central New Hampshire and northeastern Massachusetts and is shown on Plate 2. The basin has a total drainage area of about 5,010 square miles with 76 percent of this total in New Hampshire and the balance within Massachusetts. Development of the basin is mixed with several urban areas developed on the mainstem river itself, while upstream tributary areas are primarily rural.

4. Public water supply systems within the basin provided supply to about 1.2 million or about 80 percent of the 1970 basin population. Overall, communities within the basin had an average annual demand of about 140 million gallons per day.

5. Population served by public water supply systems within the basin is expected to rise to about 1.6 million in 1990 and 2.1 million by the year 2020. Water demands from the public system are expected to rise to about 236 mgd by the year 1990 and almost 390 mgd by 2020.

6. Two time periods were used in evaluating the ability of the public water supply systems to meet future in-basin needs. Short term or early action supply requirements were considered to be those needs anticipated from the present to the year 1990. Long range needs were considered to be those supply requirements established to occur in the 1990-2020 period.

7. From a short term supply perspective, there are a number of municipalities within Massachusetts primarily adjoining the mainstem river which will require augmentation of their systems if they are to meet estimated 1990 needs. These communities, shown on Plate 8, were considered in this study as possible candidates to be served by a regional system using the Merrimack River as its supply source.

8. Within the New Hampshire portion of the basin, a large proportion of the 1990 estimated needs will be met by two recently completed water treatment plants. These plants, which supply Concord and Manchester, New Hampshire and their environs, are expected to meet those region's needs through at least 1990. The Nashua, New Hampshire region, however, does not at present have existing supplies adequate to meet 1990 requirements. The potential of serving this region's needs from a water treatment plant located within Massachusetts, therefore, was evaluated as part of this study.

9. The estimated out of basin needs were developed as a supplement to yields which would be made available from other active proposals to augment existing supplies. These other proposals which include recommended actions by the Corps of Engineers, Commonwealth of Massachusetts and Regional Planning Agencies would develop sufficient yield for out of basin communities to meet 1990 needs. Development of the Merrimack River as a supply source for out of basin communities, therefore, would be to meet long range (1990-2020) needs.

10. In addition to the use of the Merrimack as a water supply source, there are also a number of allied uses for which the river is presently utilized or for which proposals have been made. These include water quality, hydroelectric power and anadromous fish restoration. Development of the river, particularly for out of basin needs, had to be evaluated in consonance with these other resource needs.

11. In the formulation of all plans, four key tests were applied. These tests were reliability, flexibility, timeliness and equity. In addition, each alternative was assessed against technical, economic, environmental and socio-economic criteria considered applicable. In accordance

with the "Principles and Standards", the beneficial and adverse affects of alternatives were outlined and compared. Where possible, alternatives were designed to reduce or minimize adverse impacts.

SHORT TERM PLAN

12. Both non-structural and structural alternatives were considered as methods to meet the short term (1990) water supply needs of the communities shown on Plate 8. Non-structural measures included such diverse methods as no development, consumer education, use of water saving devices, weather modification and waste water reuse. Structural measures include use of the Merrimack River mainstem as a source of supply for the region, desalination and development of locally available resources with the communities.

13. Analysis of the alternatives revealed that alternatives which held the greatest promise for the short term need area included water demand modification; development of the Merrimack River mainstem to provide a regional system; and development of locally available resources by individual communities and sub-regional groups of communities.

14. Of all alternatives considered, the short term plan, which meets most satisfactorily the objectives of "Principles and Standards", is a combination of non-structural and structural measures. Non-structural measures would be consumer education and use of water saving appliances. Structural measures would be those required by the individual communities to develop their locally available resources. These include construction of new in-town reservoirs; well fields for groundwater sources; community interconnections and connection to the existing regional supply system (MDC).

LONG TERM PLAN

15. The formulation of plans to meet the estimated long term (1990-2020) needs in the eastern Massachusetts region (including in basin and out of basin needs) was not carried to the same detail as those for the short term. The long range nature of these plans carry with them a degree of uncertainty which does not warrant development of specific detailed project plans. However, the alternatives were investigated in sufficient detail such that their relative ranking could be established.

16. The demand area for the long term plans include those 42 municipalities presently served by the existing MDC regional supply system: those 24 communities anticipated to join the MDC by 1990 and those 41 communities which will require service from the regional system by the year 2020. Other communities within eastern Massachusetts either had sufficient in-town resources or access to potential smaller regional systems.

17. Overall, communities which might be served by a large regional system within eastern Massachusetts have an estimated additional supply requirement of about 210 mgd. Alternatives considered to meet this long range requirement included no development; water demand modification, weather modification, wastewater reuse for municipal supply, development of the Connecticut River by high flow skimming, Plymouth County groundwater, desalination dual water supply systems and development of the Merrimack River mainstem by high flow skimming and continuous withdrawal techniques.

18. Based on present knowledge, implementation of demand modification and the Sudbury River redevelopment as components of a long term regional plan appears favorable. Each of these projects would yield a cost effective limited impact increment to the needed supply increment. These two projects by themselves, however, do not satisfy the total need. A review of the other alternatives with their economic, environmental and socio-economic impacts indicates the two most favorable alternatives to supplement those above, would be Plymouth County groundwater and the Merrimack River mainstem projects. Both of these projects have uncertainties associated with them, however, and further study would be necessary prior to implementation.

SECTION I

CONCLUSIONS

1. This report has investigated and assessed all aspects of the water supply situation within the study area. Both surface and groundwater sources are utilized within the study area for public water supply purposes. The report was divided into two distinct time frames with two different areal definitions and two distinct levels of detail. The short term study area was defined as certain communities in the Massachusetts portion of the Merrimack River Basin. The long term study area included all Massachusetts communities from, and including, Worcester County to, but excluding, Barnstable County (Cape Cod).

2. This report finds that communities within the short term study area will require source augmentation by the year 1990, and, in certain cases such as Lawrence and Methuen, needs are more urgent. The report also finds, however, that there is sufficient, locally developable water supply sources to meet these short term needs. Development of these local sources includes all of the traditional techniques of water supply source development. These techniques include use of run of the river flows - as in Billerica, Lawrence, Lowell, and Methuen; full development of groundwater sources - as in Westford, Littleton, Acton, Rowly, and Salisbury; reservoir development - as in Amesbury; use of surface goods - as Haverhill and Andover do; integrated ground and surface water systems such as Concord; connection with the MDC - Bedford; formation of small "regional" systems, such as Lowell serving Dracut, Tyngsboro and Chelmsford, and Andover serving North Andover and Tewksbury; and diversion of river flows through a high flow skimming technique such as Haverhill's planned use of the Little River. This analysis of potential safe yields indicate that the Groveland and West Newbury system may not be able to meet anticipated 1990 maximum day demands with just groundwater development. However, it is possible that surface storage could be provided to meet these demands. The communities of Pepperell and Littleton have indicated their belief that there is availability groundwater which will allow them to meet 1990 demands.

3. This report finds that water demand modification - through consumer education and the increased use of water saving appliances - are cost effective and should be considered components of any plan designed to meet the long term needs of the eastern Massachusetts region.

4. For the long term needs, this report finds that development of the Merrimack River - either by a high flow skimming technique or by continuous withdrawal with low flow augmentation provided by upstream storage -and development of the Plymouth County groundwater aquifer, are both technically feasible and least costly methods of providing the additional water which the eastern Massachusetts region is expected to require in the long term.